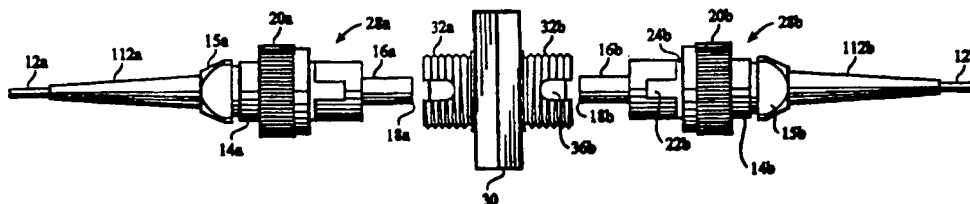




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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**(54) Title:** CAPILLARY VALVE, CONNECTOR, AND ROUTER



**(57) Abstract**

A capillary valve, connector and router where one or more cylindrical fibers, which may be capillaries, plugged capillaries, optical fibers, or the like, including at least one capillary tube (12a) are contained in a first cylindrical bundle of fibers that terminates at a first face (18a). A second cylindrical bundle of fibers also containing one or more fibers including at least one capillary tube (12b) terminates in a second face (18b) abutting the first face.

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## Description

## CAPILLARY VALVE, CONNECTOR, AND ROUTER

## 5 FIELD OF THE INVENTION

This invention relates generally to capillary valves and devices for interconnecting capillary tubes with each other, with microfabricated devices, and macroscale devices.

10

## BACKGROUND OF THE INVENTION

Capillary tubes are useful in a wide range of microfluidic applications, particularly where volumes on the order of a microliter or smaller are handled.

15 Capillaries are made of glass, metal, silica, or a polymer. The outer diameter of a capillary tube ranges from under 100 to over 750 microns. The diameter of the inner bore ranges from 2 to over 500 microns. With only minimal amounts of chemicals required, systems utilizing  
20 capillary tubes are well suited for producing high sample throughput with minimal use of space and materials. In electrophoretic applications, the high surface to volume ratio of capillaries enables the use of high voltages with low joule heating. The use with high voltages  
25 results in the ability to electrophoretically separate compounds in capillary tubes at several times the speed and resolution available with traditional slab electrophoretic separation.

Numerous applications have developed to take  
30 advantage of the benefits that capillary tubes provide. For example, one use of capillary tubes is in microfluidic devices where capillary tubes are used to transport small amounts of fluid from one location to another. Another application using capillary tubes entails temporarily  
35 sealing both ends of a capillary tube to form a nanoscale reaction vessel. Finally, chromatographic devices utilize capillary tubes to provide a separation column for substances. The substances can then be

separated based on their physical properties, such as mass, size, or shape. Such applications include gas chromatography and liquid microbore chromatography.

5 All of these applications require that sections of capillaries be connected to each other. For example, gas chromatography will require an injection port that can introduce a sample into a flow stream. The varied uses of capillary tubes require capillary connectors that are both versatile and resilient. The physical stresses  
10 placed on these capillary connectors are most demanding. The connector must be inert to reactive substances that flow through the capillaries, including organic solvents. The connector must remain leak free when used to contain a liquid, gas, or a fluid separation matrix at pressures  
15 ranging from 0 to 10,000 PSI.

In high electric voltage applications, the connector must be insulated from these voltages, which can be over 10,000 volts. The connector should add negligible additional volume to the capillary column to  
20 avoid degrading separation resolution in electrophoretic applications. In addition, the connector should be able to act as an interface for connecting macroscale devices (such as injectors, fluid reservoirs, or sample depositors) to microscale capillary tubes. Finally, to aid in  
25 the simple manipulation of the connector, the connector must be reusable and simple to connect.

The varied uses of the connector in a number of applications require that the connector serve several different functions. Primarily the connector must be  
30 able to serve as a leak free, high pressure connector for two or more capillary tubes. The connector should provide a number of other functions as well. The connector could serve as a valve, enabling both the ability to close an end of a section of capillary tubing and the  
35 ability to route fluid from one capillary tube into a selectable second capillary tube. In addition, it would be useful for the connector to function as a manifold enabling the combination of the flow streams from a

plurality of input capillary tubes to channel into a single output capillary tube or splitting a flow stream from a single capillary tube into multiple flow streams in multiple capillary tubes. The connector preferably  
5 would have negligible dead space volume, both as a connector and as a valve. Finally, the connector should enable connection of macroscale devices to microscale capillary tubes.

By combining these features within one connector, a multitude of uses become a possible. By using two  
10 such connectors at the two ends of a section of capillary tubes, a reversibly sealable nanoscale reaction chamber is formed. If the first connector also functions as a manifold, a plurality of input lines could flow into this  
15 nanoscale reaction chamber before it is sealed to allow for mixing a number of chemicals in the reaction. If the output line also functions as a manifold, once the reaction is complete, the mixture could be divided into multiple lines for sending flow streams to multiple  
20 analytical devices or to a waste reservoir.

In the past, several couplers have been developed to attach together the ends of capillary tubes. Some capillary connectors employ a ferrule with a longitudinal bore therethrough for inserting the ends of the  
25 capillaries to be coupled together and a compression fitting for mechanically compressing the ferrule to seal the connector. U.S. Pat. No. 5,288,113 to P.H. Silvis et al. teaches a heat-resistant connector for releasably joining end portions of two capillary tubes in end-to-end  
30 fashion for use in chromatography. U.S. Pat. No. 5,540,464 issued to Picha, describes a capillary connector where the ends of a capillary tube are press fit into a resilient member with a tapering throughbore. A split sleeve holds a pair of these members together in mutually  
35 facing alignment, with the throughbore aligned to enable two capillary tubes to come into fluid communication. U.S. Pat. No. 5,453,170 to S. Krstanovic et al. teaches

coupling a capillary to a fine wire electrode to form an ion detector.

Some of the capillary connectors demonstrate the ability to couple together more than two capillaries. 5 U.S. Pat. No. 5,487,569, issued to Silvis et al., teaches a glass insert with a plurality of legs connected at a central portion. Each leg has a tapered inner bore that receives one end of a capillary tube. On each of these legs is annularly mounted a connecting member containing 10 a sealing ferrule for making a seal between the capillary and the leg. U.S. Pat. No. 5,494,641, issued to Krstanovic, describes a system for connecting any number of capillary tubes into a system by mounting the capillary tube within a cavity in a mechanical fastener. The 15 capillary tube can then be attached to any apparatus that has been adapted to accept the fastener.

These capillary connectors function to link sections of capillary tubes. It would be advantageous to have a connector that could serve other functions.

20 Currently, there are several devices that have been used as valves or gates for capillaries. One capillary valve requires that the capillary tubes be attached to holes in a thin wafer, such as a silicon wafer. A flexible membrane is positioned on the opposite 25 side of the wafer. By exerting pressure on the membrane, the membrane is pressed against the holes in the silicon wafer and the valve is closed. U.S. Pat. No. 5,492,555, issued to Strunk et al., describes a two dimensional capillary gas interface. One part of the device is a 30 bimodal six way capillary valve. This valve comprises a cylindrical section with a longitudinal axis perpendicular to the plane containing the longitudinal axis of three sections of capillary tubes. The valve operates by rotation of the cylindrical section to align the ends of 35 the capillary tube in the tangential plane of the cylinder with the ends of other capillary tubes bringing the section into fluid communication. Further rotation will bring the ends of the capillary tubes in the rotating

cylindrical section out of communication with the capillary tubes, closing the valve. This valve has significant dead volume of several microliters.

5 The inner diameters of capillary tubes must connect to devices that are an order of magnitude or more larger. This has been a persistent problem for the field of microfluidics. Some attempts have been made to provide for a macroscale to microscale interface. For example, capillary tubes have been attached to pressurized reservoirs. An inlet to the reservoir is capped by a rubber septum. A macroscale injector, such as a syringe, can introduce a sample into the reservoir, and the sample will be pressure driven into the capillary tube. After repeated injections through the septum, the septum will no longer remain pressure tight and will require replacement.

Both the connectors and the valves presently available are not ideal. None of these devices combine in one connector the ability to connect a number of capillaries, but also to act as a zero dead volume valve, or as a manifold, or as a router of fluid. As noted above, such a connector would greatly enhance the utility of many systems that use capillary tubes. Furthermore, no device presently available is an adequate interface between macroscale and microscale devices. An object of the invention was to provide improved connectors and valves for capillaries and to connect macroscale devices with macroscale devices.

### 30 SUMMARY OF THE INVENTION

The above object has been achieved with a capillary connector which is able to join into fluid communication a plurality of capillary tubes, but also can function as a valve, a fluid router, a manifold, a reaction chamber and a macroscale to microscale connector. Each connector is simple in design and is rapidly and easily connected and disconnected. The connector has negligible dead volume whether functioning as a capillary

tube connector, a valve, a fluid rotor, a manifold, a reaction chamber or a macroscale-to-microscale connector.

The basic connector consists of two members, with each member consisting of the same basic parts.

5 Each member includes an input bundle of fibers, which are usually capillaries, entering the member, with the input bundle terminating in a ferrule rotatably attached to the member. The input bundle is a set of one or more axially parallel, packed cylinders or fibers, at least one of  
10 which is usually a capillary tube, but which also can include non-hollow fibers, such as plugged capillaries, electrodes and fiber optical fibers. The fibers terminate at the end of the ferrule. A fastener connects these two members and holds the ends of the ferrules in  
15 mutually biased axially parallel alignment. The rotatable ferrules can then be rotated in relation to each other. The fibers packed within the ferrule would be affixed within the bundle and ferrule and be relatively non-rotating in relation to the bundle and ferrule. By  
20 rotation of the ferrules, the rotational orientation of the fibers about an axis in the first bundle would be altered in relation to the orientation of fibers about the same axis in the second bundle, but the axially parallel alignment would remain.

25 Each member of the connector could have an indicator to indicate the rotational orientation of each ferrule. In one embodiment, the indicators consist of a mark or notch on the ferrule above the centered location of a capillary tube. Alignment of the marks on the two  
30 ferrules would indicate that corresponding capillary tubes within the ferrules were aligned and in fluid communication.

With this basic connector, several different functions are possible. The connector can function to  
35 put two corresponding capillary tubes into fluid alignment and thus function as a basic connector. Unlike other available connectors, this connector would also function as a connector between macroscale devices and



microscale capillary tubes. It can also function to connect multiple capillaries in one member to a second member with either an equal number of capillaries or with only a single capillary.

5           In addition, the connector can function as a valve. When the ends of the capillaries in both ferrules are aligned, the valve is open. If the ferrule of the second member is rotated in relation to the orientation of the first ferrule, the ends of the capillary tubes can  
10 be displaced in relation to each other so that non-corresponding solid cylinders, which may be glass fibers, metal, plastic or a plugged capillary, are aligned with the capillaries and the ends of the capillary tubes will be blocked or closed. These cylinders are generally  
15 referred to as non-hollow fibers and plugged capillaries, since these are preferred elements, the main consideration being an outer diameter which is the same as a corresponding capillary which it faces at a ferrule-to-ferrule interface. In other words, when non-hollow  
20 fibers are contained within the ferrule of a first connector member, the flow within a capillary could be blocked by orienting the ferrule of a second connector member such that the end of the capillary of the second connector member and the end of the non-hollow fiber of  
25 the first connector member are in alignment. The valve is also closed whenever the ends of the capillaries are not aligned with capillaries on the opposing member, including when the ends are aligned with the inter-capillary surfaces. This valve that is created has  
30 essentially no dead volume and is simple to manipulate by rotation. The alignment marks, scale or notches on the ferrules would indicate if the valve is open or closed. A calibrated scale will allow partial blockage of a capillary by incomplete overlap with the open end of a  
35 capillary. If the non-hollow fibers are fiberoptic fibers, alignment could be indicated by passing light through the fibers and detecting if the light passes through a distal end of the fiber. This rotatable valve

can also function as a router. For example, if capillaries aligned on ferrules of both members are rotated such that capillaries on a first member now align with different capillaries on the second member, a router is  
5 created. Similarly, depending on the application, some capillaries on the first member can be routed to capillaries on the second member, while other capillaries are closed.

Typically, rotation of the ferrule is effected  
10 by manual operation. It is also possible to operatively associate the ferrule with a motor to effect automated controlled rotation of the ferrule. The motor would operate in accordance with instructions from a controller that a user would program to give desired results. The  
15 orientation of the ferrules would then be automatically controlled with precision timing for volumetric accuracy, especially if variable blockage of a capillary is implemented.

The basic connector, comprised of the two  
20 connector members mutually biased against each other, readily transforms into a manifold. This would require that one of the ferrules be associated with a bundle of packed capillary tubes and the second ferrule be associated with a bundle containing one capillary tube.  
25 Between these two ferrules would be placed a washer with a cut out pattern. The cut out pattern would bring into fluid communication the flow streams of the plurality of tubes in the first ferrule with the inner bore of the single capillary in the second ferrule. The same result  
30 could also be achieved by slightly recessing the capillary tube in one ferrule and having a groove extend between the recessed capillary tubes. This would allow the inner bore of the capillary tube in the second ferrule to come into fluid communication with the first  
35 set of capillary tubes. Alternatively, a plurality of capillary tubes in one bundle and ferrule can be associated with a single capillary tube in another bundle and ferrule whereby the inside diameter of the single capil-

lary is large enough to encompass more than one capillary tube in the other ferrule.

This basic connector is adaptable for many different uses. By placing oppositely charged electrical leads on the opposite sides of connector members and filling the tubes with a conducting media, the media will conduct electricity without shorting on the connectors. This enables capillary electrophoresis reactions to be run in the tubes joined by these connectors.

In addition to the use of the present invention wherein two connector members are joined together, the invention also can be used as a single connector member that could be joined to any other device that contains a port member to receive the connector member. This connector member would be comprised of a rotatable ferrule containing at least one capillary tube terminating at a substantially level surface. An alignment indicator on the ferrule, such as a mark or notch, would indicate the orientation of the capillary tubes within the ferrule. The member would have an attachment device, such as an annular nut, capable of attaching to a mating mount, such as a threaded protrusion of a receiving well. This would allow a capillary to be joined to any of a variety of port members, including attachment to a port member of a moveable arm for the deposition of an array of spots on a surface. The moveable arm would allow placement of such spots in different locations. By including multiple capillary tubes within the ferrule, the connector member could mix compounds on a spot or could be attached to a receptacle for deposition of the reactants to be mixed.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a side view of two connector members and a fastener for the members according to the present invention.

Fig. 2 is a perspective view of a single connector member shown in Fig. 1.

Fig. 3 is an exploded perspective view of a connector member shown in Fig. 2.

Fig. 4 is an exploded perspective view of the fastener shown in Fig. 1

5 Fig. 5 is a perspective view of the fastener member shown in Fig. 4.

Fig. 6 is a side cutaway view of an alternate embodiment of a single connector member joined to a fastener.

10 Fig. 7 is a perspective view of a portion of a ferrule for a connector member of the type shown in Fig. 1.

Fig. 8 is an end view of the ferrule shown in Fig. 7.

15 Figs. 9a and 9b are schematic sectional views showing non-rotatable fibers at ends of rotatable ferrules of the type shown in Fig. 7 function as a valve.

Fig. 10 is a schematic sectional view showing ferrules of the type shown in Fig. 7 combined with a washer functioning as a manifold.

20 Fig. 11 is a schematic sectional view of two rotatable ferrules of the type shown in Fig. 7 functioning as a fluid router.

Fig. 11a is a schematic sectional view of two rotatable ferrules of the type shown in Fig. 7 functioning as a fluid router.

25 Fig. 12 is a plan view of a number of connector members of the type shown in Fig. 1 used for a macroscale injector injecting fluid through a microscale capillary tube.

30 Fig. 13 is a plan view of the injector of Fig. 12 with an additional connector of the type shown in Fig. 1 functioning as a fluid router.

Fig. 14 is a plan view illustrating a sample loading and unloading apparatus using connectors of the type illustrated in Fig. 1.

Fig. 15 is a plan view illustrating a nanoscale PCR apparatus using connectors of the type illustrated in Fig. 1.

Fig. 16 is a plan view illustrating a system with capillary electrophoresis and laser induced fluorescence to detect DNA using connectors of the type illustrated in Fig. 1.

Figs. 17a-17e are schematic sectional views of ferrules with multiple fibers in closely packed geometric arrangements.

#### BEST MODE OF CARRYING OUT THE INVENTION

With reference to Fig. 1, a connector is adapted from a standard FC-style fiber optic connector, consisting of a first connector member 28a and a second connector member 28b joined by an adapter 30. The first connector member 28a has a first capillary 12a entering a ring 14a and extending into rotatable ferrule 16a. The capillary 12a is fixedly attached within rotatable ferrule 16a and terminates at end 18a of rotatable ferrule 16a. The end may be flat or, more typically, have a slight radius.

In a similar manner, in the second connector member 28b a second capillary 12b enters a ring 14b and extends into rotatable ferrule 16b. The capillary 12b is fixedly attached within rotatable ferrule 16b and terminates at end 18b of rotatable ferrule 16b.

An adapter 30 located between the two connector members 28a and 28b join the two connector members. Rotatable ferrule 16b is mounted into externally threaded cylindrical protrusion 32b. The orientation of an internally threaded knurled nut 20b in relation to externally threaded cylindrical protrusion 32b is determined by key 22b extending from key ring 24b which is coaxial with capillary 12b. Key 22b fits into gap 36b in externally threaded cylindrical protrusion 32b. Knurled nut 20b is rotated about externally threaded cylindrical protrusion 32b to securely attach connector member 28b to

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adapter 30. In a similar manner, rotatable ferrule 16a is mounted into externally threaded cylindrical protrusion 32a. Knurled nut 20a is rotated about externally threaded cylindrical protrusion 32a to securely attach  
5 connector member 28a to adapter 30.

When connector members 28a and 28b are joined together, the ends 18a and 18b are pressed together within adapter 30. The capillaries 12a and 12b can then be brought into alignment if symmetrically affixed within  
10 ferrules 16a and 16b.

A ferrule 16a can terminate a set of one or more fibers. This set of one or more fibers can be a single capillary tube or can be a plurality of fibers, at least one of which is a capillary tube. The capillary  
15 tube is made of glass, silica, metal, polymer, or other materials. In the preferred embodiment, any non-hollow fibers included are fiber optic fibers or capillaries that have been plugged with material, such as epoxy.

Strain relief boots 112a and 112b are preferably included extending from and mounted within faceted heads 15a and 15b of knurled cylinders 20a and 20b to prevent mechanical stresses from bending or breaking the fibers contained within cylindrical sleeves 12a and 12b.  
20

Fig. 2 shows a connector member 28 as assembled. A capillary 12 enters connector member 28 passing through strain relief boot 112, through connector 170 and terminating at end 18 of ferrule 16. Nut 20 is annularly disposed about connector 170.  
25

Fig. 3 shows coaxial component parts for assembling one of the connector members 28a or 28b along an axis A. The strain relief boot 112 is inserted into an end of externally threaded hollow bolt 120. The annular exterior lip 114 of boot 112 is secured against the annular interior lip 124 of faceted head 15. Once  
30 boot 112 is inserted into bolt 120 a compression ring 132 is inserted into bolt 120 at opening 129 and slid to the head end of bolt 120. Compression ring 132 will fit tightly into bolt 120. Next spring 134 is slid into  
35

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opening 129 of bolt 120 and rests on a shoulder inside of connector body 170.

Capillary 12 extends into head opening 127 of hollow bolt 120 and passes through bolt 120 and into  
5 ferrule 16. The capillary terminates at end face 18 of ferrule 16. Epoxy 136 holds the capillary 12 in place at the end face 18 of ferrule 16.

Ferrule 16 is typically a metal or ceramic cylindrical body having an axial hole into which the  
10 capillaries or fibers are secured in place. The ferrule is either press fit or epoxied into ferrule stem 150. Ferrule 16 has an outer diameter tolerance of minus zero, plus one micrometer. The hole is axially bored to an axial tolerance ranging between 2 to 15 micrometers,  
15 depending on capillary diameter and number of capillaries. The space between capillaries is filled with epoxy. The annular flange 152 is notched with notches 154. Four notches are disposed about annular flange 152 with each notch being equally separated.

20 Knurled nut 20 is fit over the assembly of hollow bolt 120. Hollow cylinder 170 is then fit over ferrule 150 and inserted inside knurled nut 20. An annular flange 172 on hollow cylinder 170 fits against annular interior lip 164 on knurled nut 20. Hollow  
25 cylinder 170 then extends over ferrule 150 with interior annular lip 178 forced against annular flange 152. Cylinder 120 is rotated onto the mating interior threads 176 of cylinder 170. As cylinder 170 is fully tightened down onto bolt 120, internal annular lip 178 is forced  
30 against annular flange 152 on ferrule 150 forcing the opposite side of flange 152 against spring 134. The tabs 128 extending from the rim of opening 129 on bolt 120 will fit into the notches 154 in annular flange 152, holding ferrule 150 rotationally secure. As cylinder 170  
35 is fully tightened, spring 134 will compress, pressing against annular flange 152 and biasing ferrule 150 from within bolt 120 with about twenty grams of force.

A key ring 24 with a key 22 is fit over hollow cylinder 170 and the two prongs 184 fit into two of the six notches 174 disposed about annular flange 172.

Several methods exist for rotating the orientation of the ferrule. First, by rotating the ferrule assembly 149 one quarter turn, a new pair of notches 154 will align with prongs 128. This enables four different orientations of ferrule 150. In addition, by rotating key ring 24 in relation to cylinder 170 different notches 174 on annular flange 172 will align with ring prongs 184. The annular flange 172 has six notches 174 disposed about the flange. This enables six different orientations of the ferrule 150 position relative to the key 22.

In an alternative embodiment, key ring 24 is made without ring prongs 184, or the key ring 24 is not used. This would result in a cylinder that is may be freely rotated in the adaptor. By turning the hollow bolt 120, ferrule assembly 149, which is non-rotatably held within the assembly of hollow bolt 120 and hollow cylinder 170, would then also rotate, altering the orientation of the non-rotating end fibers epoxied into ferrule 150.

Fig. 4 shows the component parts for assembly of adapter 30. The rear faceplate 260 has a cylindrical indentation 262 and an annular lip 264. Rear hub 220a fits within rear faceplate 260 with the annular lip 226a on hub 220a fitting against lip 264 with hollow cylindrical protrusion 226a on hub 220a extending beyond the lip and into exteriorly threaded cylindrical protrusion 32a on rear face plate 260. Cylinder 240 coaxially aligns hub 220a and hub 220b. Into hollow cylindrical protrusion 226a of rear hub 220a split zirconia sleeve 230 is inserted, with sleeve extending to near the end of cylinder 226a, stopped at a lip therein. Front hub 220b fits into the other end of cylinder 240 and the other end of sleeve 230 fits into cylindrical protrusion 226b. Front face plate 250 fits to rear face plate 260. Cylinder 240 fits within front face plate 250 and cylin-



drical protrusion 226b extends through face plate 250 into cylindrical protrusion with exterior threading 32b. Screws 214 insert into holes 216 on front face plate 250 and screw into holes 217 on rear faceplate 260.

5                    Fig. 5 shows the assembled adapter 30. Screws 214 have been inserted through front face plate 250 to attach it to rear face plate 260. Alternatively, other forces may be applied to keep face plates 250 and 260 together. The face plates could be rounded to form a  
10 driven gear for rotation by a motor discussed below. Cylindrical protrusion 226b extends through face plate 250. Fitted within protrusion 226b is split zirconia sleeve 230. Sleeve 230 is a loose fit inside of hubs 220a and 220b. Exteriorly threaded cylindrical protrusion 32b extends from the center of the fastener.  
15

The fitting of adapter 30 with connector member 28 is shown in Fig. 6. In Fig. 6, a bundle of fibers 212, at least one of which is a capillary, enters the connector through stress relief boot 112 and proceeds  
20 into hollow bolt 120. The epoxy coating 213 is only one to a few microns thick. Within the hollow bolt 120, bundle of fibers 212 is attached within ferrule 150 by epoxy 213. The ferrule terminates at face 18. The end faces of the ferrules have a spherical shape, i.e.  
25 radiused, to further ensure a leakproof joint. A typical radius of curvature is 5-30 mm. By curving the end faces, the requirements for polishing the end faces are greatly reduced. The end faces are polished such that the central portion of the end face 18, containing the  
30 capillaries, comes in contact before the outer portion of the end face. This eliminates the need to polish a flat end face to 0° perpendicularity to the capillary. Non-zero degree end face polish would cause an air gap, leading to leakage.

35                    Ferrule 150 has a circular annular flange 152 which is held against cylinder lip 178 and biased against lip 178 by spring 134. The spring is held in threaded

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cylinder 120 by compression ring 132. Compression ring 132 is held in place by annular bolt head lip 121.

Internally threaded cylinder 170 is screwed to hollow bolt 120. The interior of cylinder 170 has an annular lip 178 that holds circular flange 152 of ferrule 150. On the exterior of cylinder 170, an annular circular flange 172 abuts annular lip 164 of knurled nut 20. Nut 20 screws onto an exteriorly threaded cylindrical protrusion 32 on rear face plate 260.

On rear face plate 260, cylinder 240 is mounted annularly to hub 220 with hub lip 228 abutting rear face plate lip 264. Cylindrical protrusion 226 extends through rear face plate 260. Mounted within cylindrical protrusion 226 is split zirconia sleeve 240. Zirconia sleeve 240 acts as a spring to align outer diameters of ferrules 150. Inside zirconia sleeve 240 frictionally fits ferrule 150 with the bundle of fibers 212. With nut 20 tightened as shown, the connector member and fastener are securely attached together, and the spring is compressed, thereby compressing end faces, creating a leakproof joint. Typical spring force when fully assembled is two pounds.

A stepper motor 178 may be used to rotate a gear 179, turning meshing gear 177 to rotate ferrule 150 through external teeth on a fully round nut 126 or on a round adapter member 260 having external gear teeth 261, which may be moved by a gear 179. Motor 178 may operate under control of an automatic controller 181 which is programmed to achieve desired valve settings at desired times. The controller allows selectable alignments of a first ferrule relative to a second ferrule.

With this basic connector, a number of uses become possible. As mentioned above, the bundle of fibers 212 contains at least one capillary tube. In one embodiment of this invention, each of the two abutting ferrules of a connector contain three fibers. By rotating these two ferrules in relation to each other, the fibers within the ferrule would be brought into or out of

alignment. A non-hollow fiber, typically a plugged capillary tube, could be brought into alignment with a capillary tube, effectively blocking flow through the tube. This would allow the connector to act as a switch.

5 By having one member of the connector contain a bundle of fibers having multiple capillary tubes and the second member contain a bundle of fibers with one capillary, a 3-to-1 fluid router is formed. If a channeling device is located between a ferrule containing multiple capillary  
10 tubes and a ferrule containing a single capillary tube, a manifold is formed. Finally, the connector can be used as an interface between macroscale devices and microscale capillary tubes.

Fig. 7 shows a rotatable ferrule 150. The  
15 ferrule is adapted from a FC-style fiberoptic connector. At tip 18 of ferrule 150 the ends of three fibers are seen. These fibers are a capillary tube 100 and two fiber optic fibers, 101 and 102. The capillary and the fibers should have the same outside diameter for closest  
20 packing. To adapt the invention from the FC-style connector, a FC-style connector is modified by precision drilling of the ferrule to produce a hole within a few microns of the size of the bundle of fibers. Within a FC-style connector, the bundle of capillaries can contain  
25 a single capillary, three capillaries, seven capillaries (packed with one central capillary and 6 radial capillaries), or nineteen capillaries (packed with twelve capillaries surrounding six capillaries surrounding one capillary), or any symmetrical arrangement of fibers or  
30 capillaries. Any of the capillaries can be replaced with either a plugged capillary or a fiber optic fiber of equal outside diameter.

To make a three fiber FC-style connector, the  
hole of a FC-style connector is drilled to accommodate  
35 the exterior diameter of a bundle of three fibers. The three-fiber bundle is inserted and centered where the bundle consists of three capillaries, the capillaries are inserted and secured in place with epoxy with the ends of

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the capillaries protruding from the face of the ferrule. The end of the capillaries is then polished back with a slight radius.

Fig. 8 shows the end of a ferrule after one unplugged capillary and two plugged capillaries have been inserted and secured in place. A band of epoxy 136 extends axially and secures the capillary tubes in place. A capillary tube 100 with an interior bore 105 and two plugged capillaries 101 and 102 terminate at the end of the ferrule 18. The material comprising the unplugged capillary tube 100 and the plugged capillaries 101 and 102 has been polished back with a slight radius.

This basic embodiment of this invention is readily useable as a zero dead-volume slide valve. A schematic for the connector performing this function is shown in Figures 9a and 9b. Fig. 9a shows a representation of the connector when closed. A first ferrule section 45 and a second ferrule section 50 are shown. In the connector, fiber ends, i.e. capillaries, would be in facing alignment and biased against each other in the fastener of the connector. Both of the sets of fibers within the ferrule are offset from the center and precisely mounted with a standardized orientation on the ferrule. This is effected such that plugged capillary 42 in ferrule section 45 could align with capillary tube 46 in ferrule section 50. In a similar manner, plugged capillary 43 in ferrule section 45 would align with plugged capillary 48 in ferrule section 50 and capillary tube 41 in ferrule section 45 would align with plugged capillary 47 in ferrule section 50. Because the two capillary tubes are aligning with non-hollow fibers, no fluid would be able to pass through either of the capillaries and all capillaries in this valve would be closed.

The valve could be opened by rotating ferrule section 50 with a one-third turn. This results in the orientation shown in Fig. 9b. Now capillary tube 41 in ferrule section 45 would align with capillary 46 in ferrule section 50. Fluid would then be able to flow

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through from one capillary to the other. Plugged capillaries 42 and 43 in ferrule section 45 would align with fibers 48 and 47 in ferrule section 50 respectively.

5 The methods of rotating the ferrules were set out above. When the ferrule is rotated, there needs to be some indication of the alignment of the fibers within the sleeve. This would allow the user to determine if the valve was in an open or closed position.

10 A first indicator of the orientation of the fibers within a sleeve would be to use markings or notches on hollow cylinder 120. The marking could be located near the end 15 of hollow bolt 120.

15 When two members of the connector are secured together, the markings on the two cylinders of the two members could indicate the orientation of the fiber bundles secured within the connector. This would indicate the orientation of the fibers located inside the bundles.

20 A second method of determining alignment would be through the use of optical properties of the fiber optic fibers. By including a fiber optic fiber in each side of the connector, the fiber optic fibers could act as an alignment indicator. Within the bundles, the  
25 fibers were in alignment the capillary tubes would also be in alignment. By attaching the distal end of a fiber optic fiber contained within one bundle to a light source and attaching the distal end of a second fiber optic  
30 detector the fiber optic alignment indicator would be enabled. When light is provided to the distal end of one fiber and is detected at the distal end of the second fiber this indicates that the fiber optic fibers are precisely aligned. The capillary tubes that are in a  
35 fixed relation to the fiber optic fibers would then also be aligned. This alignment system would be very highly accurate because the light would only pass through the fiber optic fibers only if they were precisely aligned.

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The simplest example of a manifold would be a connector that channels the contents from two capillary tubes to one capillary tube. One embodiment of this system is shown in Figure 10. A first ferrule 65 contains two capillary tubes 57, 58 and one plugged capillary 56. The second ferrule 69 contains one capillary tube 63 and two plugged capillaries 62 and 61. A washer 60 is located between the two ferrule ends 65 and 69. The cut out 67 of the washer 60 would be in the shape of a V with the width of each leg of the V as wide as the diameter of the inner bore of the capillary tube with the greatest bore width.

When the manifold is assembled, ferrule end 65 is aligned end to end with ferrule end 69 with washer 60 located between the two sleeve ends. The two capillary tubes 57 and 58 funnel fluid into the top of the V in cut out 67 and the fluid would flow down into the point of the V where the single capillary 63 would receive this flow. In this manner the fluid in two tubes would be combined into a single tube.

The washer can be adapted to combine more than two tubes. Additional legs could be added to channel the fluid from a greater number of tubes into a single tube or multiple tubes in an opposing ferrule.

An alternative means to achieve the manifold function can be realized by recessing the ends of the capillary tubes in one ferrule from the end of that ferrule. The fluid would exit the capillary tubes and be pressure driven to the inner bore of the other capillary.

A schematic of the connector functioning as a fluid router is shown in Figure 11. Two ferrule sections 70 and 80 are shown. Ferrule 70 contains a plugged capillary 71, and six radial fibers 72-77. One of the radial fibers is a capillary tube 77, the others are five plugged capillaries 72-76. Ferrule 80 contains a central plugged capillary 81 and six radial fibers 82-87. All of the radial fibers are capillary tubes. When the capillary tubes are of the same diameter, close packing is

possible and highly recommended. For this reason, plugged capillaries are preferred to optical fibers; namely, size matching is easier for open and plugged capillaries. Close packing of fibers on opposite sides of a valve leads to good fluid communication between opposite sides of a valve, without leakage or cross-contamination and aids in alignment of opposing capillaries.

As initially shown, the single capillary tube 77 in ferrule 70 is aligned with capillary tube 83 on ferrule 80. This allows fluid communication between the two capillary tubes 77 and 83. The other ends of capillary tubes 82, 84-87 in ferrule 80 would be blocked by plugged capillaries 72-76. Ferrule 80 could then be rotated by 1/12 of a turn clockwise. This would align capillary 77 in between capillaries 87 and 82 and would act as a closed valve for all positions. Ferrule 80 could then be rotated by a further 1/12 turn clockwise. This would align capillary tube 77 in ferrule 70 with capillary tube 82 in ferrule 80. Fluid communication between capillary tube 77 and capillary tube 82 is now possible. All the other capillary tubes in ferrule 80 are blocked by plugged capillaries in ferrule 70. By further subsequent rotations of ferrule 80 each of capillaries 82-87 could be brought into fluid communication with capillary 77 in ferrule 70.

With reference to Fig. 11a ferrule 70 is seen to contain plugged capillaries 71, 73, 74 and 75. On the other hand, capillary tubes 72, 76 and 77 are each open and may carry different reagents or samples. Ferrule 70 abuts ferrule 80 which has one plugged capillary 81 and open capillaries 82, 83, 84, 85, 86 and 87. When ferrules 70 and 80 are brought into an abutting relationship, the three capillaries 72, 76 and 77 and ferrules 70 may distribute fluid among the six capillaries in ferrule 80 by selective rotation of ferrule 70 with respect to ferrule 80.

Some of the uses for the present invention are illustrated by the following examples:

#### EXAMPLE 1: INJECTOR

5 As is illustrated in this example, the connector described above is adaptable for acting as an interface between macroscale devices, such as syringe pumps or injectors and microscale capillary tubes. Fig. 12 shows an injector apparatus. In this drawing, the connectors  
10 are pictured with the fastener cut away to reveal the interior of the associated ferrules. Representations of the ferrule face are pictured above each connector member.

In this embodiment, the injector is comprised  
15 of syringe 300 with a plunger 302 controlled by controller 304. The needle 308 of the syringe 300 terminates in ferrule 326 of connector member 322. A representation of the end of the ferrule 306 shows that the end of the needle 347 is a macroscale tube of up to 1 mm in diameter. The second connector member 324 contains a single  
20 microscale capillary tube 325. Capillary tube 325 extends from second connector member 324 and the opposite end of the length of capillary 325 terminates in ferrule 331 of connector member 332. Ferrule 331 contains a  
25 triplet packing of fibers shown in icon 335 which shows the capillary tube 325 and two plugged capillaries or fiber optic fiber ends 337 and 336. Ferrule 331 is in alignment with ferrule 333 of connector member 334. Ferrule 333 also contains triplet packing of fibers shown  
30 in icon 345. Terminating at the face of ferrule 333 are three fibers, capillary tube 344, capillary tube 342 and plugged capillary 346. Ferrule 333 would be rotated such that the bores of capillary tube 325 and capillary tube 344 were in alignment. Capillary tube 344 terminates at  
35 ferrule 349 attached to the optional connector member 348. This member is mounted on reservoir 350 with the capillary tip submerged.



The controller 304 could withdraw plunger 302 forming a vacuum that would draw fluid from reservoir 350 through capillary tube 344 through capillary tube 325 and into barrel 305 of syringe 300.

- 5                Sleeve 333 could then be rotated such that the inner bore of capillary 342 was aligned with the inner bore of capillary tube 325. Controller 304 then can depress plunger 302 forcing fluid through needle 308, into capillary tube 325 and into capillary tube 342.
- 10              This system allows injections of determined amounts of fluid to be introduced into a flow stream.

#### EXAMPLE 2: INJECTOR WITH FLUID ROUTER

- Once the basic injector has been developed, the
- 15              connector members allow for a number of expanded functions. Fig. 13 demonstrates how the previously described injector can be expanded to include a fluid router. Like the previous apparatus, a controller 304 operates a syringe 300. The controller can depress plunger 302
- 20              forcing fluid into needle 308. Needle 308 terminates at ferrule 364 of connector 370. Fluid is transferred into capillary tube 372 located in ferrule 336.

- The distal end of capillary tube 372 terminates at ferrule 376. The end of ferrule 376 is pictured at
- 25              icon 395. Capillary tube 372 is the sole capillary tube within the bundle of fibers in ferrule 376. The bundle contains 7 fibers, with one fiber surrounded by six other fibers. Capillary tube 372 is packed with plugged capillaries 391 - 396. Ferrule 376 is in alignment with
- 30              ferrule 378. Ferrule 378 also contains 7 fibers, a central plugged capillary 392 around which is packed six capillary tubes, 380, 382, 384, 386, 388, and 390. As pictured, capillary tube 372 in ferrule 376 is in alignment with capillary tube 384 in ferrule 378. All the
- 35              other capillary tubes in ferrule 378 are blocked by the plugged capillaries in ferrule 376.

By rotating ferrule 376 one-sixth turn counter-clockwise, capillary tube 372 would be aligned with

capillary tube 386. By performing subsequent one-sixth rotations of ferrule 376, capillary tube 372 could sequentially be brought into fluid communication with each of the six capillary tubes in ferrule 378. Thus the fluid from syringe 300 could be directed to any of six capillary tubes affixed within ferrule 378. The capillary tubes contained within ferrule 378 then could be connected to a variety of analytical equipment. One or more of the capillary tubes could be connected to a reagent or wash reservoir. This injector could withdraw liquid from a reservoir attached to one of these lines and then could route the fluid into the other capillary tubes.

### EXAMPLE 3: SAMPLE LOADING AND UNLOADING

With reference to Fig. 14, a first automated syringe pump 601 is operated by a microstepper motor 603 controlled by an electronic controller, not shown, driving a very fine screw 605 linked to the plunger of the syringe. The syringe has a barrel 607 whose cross section is shown by the icon 609 and is connected to adapter 611. The opposite side of the adapter 611 is connected to a first capillary storage section 613 having a known volume. This storage section is optional. The cross section of the storage capillary is shown by the icon 615. The capillary storage section is connected to an adapter 617 which links the first capillary storage section to a second capillary storage section 619 whose cross section is shown by the icon 621. The second capillary storage section, like the first section, has a known storage volume. The capillary storage section is bundled with two fibers which are plugged capillaries, as indicated by icon 625, showing the cross section of the three fibers, one of which is unplugged and is the capillary 619. The three fibers are linked to adapter 623 in the manner previously described with reference to Fig. 1, forming a first two-to-one branching valve 623. The output side of the branching valve has a cross

section shown by icon 627 with two unplugged capillaries and one plugged capillary. One of the branches is capillary 629 having a cross section indicated by icon 633 and leading to a fluid reservoir 631. This reservoir  
5 contains a supply reagent which is to be injected into the system using the first syringe pump 601. The second output member of the branching valve 623 is the capillary storage section 635 having a cross section indicated by icon 637 and joined to adapter 639. Once again the  
10 capillary storage section 635 holds a known volume of fluid which may be pumped to other sections.

The adapter 639 joins a fourth storage capillary, having a cross section indicated by icon 643 to a second two-to-one branching valve 645 having an  
15 input section indicated by the icon 647. The icon 647 shows one plugged capillary section and two unplugged sections. One of the unplugged sections is the storage capillary 641 while the other is a capillary 651 in order to communicate with a plurality of wells 653 in the  
20 movable microtiter plate 655. The microtiter plate moves in X, Y and Z directions to bring the wells 653 into fluid communication with the tip of capillary 651. The output of the branching valve 641 is a fixed volume storage capillary 657 which is connected to a two-to-one  
25 branching valve 659. The output of the two-to-one branching valve 645 has a cross sectional shape indicated by the icon 649, with two plugged capillaries and one open capillary. Icon 661 has a similar configuration for the input side of branching valve 659. On the other  
30 hand, the output side of branching valve 659 has two open capillaries and one plugged capillary, indicated by icon 663. One of the capillaries 665 leads to the second syringe pump 671 via an adapter 670 with the input side having a cross sectional shape indicated by icon 667 and  
35 an output capillary having a cross sectional shape indicated by icon 669. The output is affixed to the barrel of the second syringe 671. The second output of valve 659 is a capillary of known volume 673 which

terminates in a ferrule 677 which is linked to the main process flowstream which utilizes samples which have been loaded onto the microtiter plate 655 and then unloaded.

As may be seen from Fig. 14, samples may be drawn from reservoir 631 and pumped in known volumetric quantities by the first automated syringe pump 601 into storage capillaries 613, 619, 635, 641 and 657. The portion of sample in 657 may be pumped by means of the second pump 671 into capillary 651 for loading of the microtiter plate 655.

In withdrawing sample from the microtiter plate, the second pump 671 may be used to draw sample from a well to the storage capillary 657 and then the first pump used to push sample into the storage capillary 673 for advancement into the main process stream. In this manner, samples may be loaded from the microtiter plate and then withdrawn by the push-pull action of the first and second pumps. Alternatively, samples could be deposited into a microtiter plate, onto the surface of a microarray, or into a microchip for further processing or analysis.

An alternate embodiment can use a series of pairs of valves, such as 645 and 659, with a series of sampling capillaries, i.e. 651, to produce a series of samples if each pair of valves is separated by a capillary of fixed length. In an extension of this embodiment, the second pump 671 could use a fluid router, as shown in Fig. 13, to sequentially or simultaneously withdraw multiple samples from a microtiter plate or other source of sample. This will increase throughput for high throughput applications.

#### EXAMPLE 4: NANOSCALE PCR

The system described with reference to Fig. 15 can be utilized to create a system for performing the polymerization chain reaction on a nanoscale level requiring as little as a few microliters total reaction volume. Although this example shows PCR for a single DNA

sample, the apparatus may be combined with the apparatus of the prior example so that multiple samples can be handled. While this example shows an implementation for PCR, alternate embodiments are applicable to other  
5 biochemical and chemical reactions, including those that use only a single temperature.

The basic idea for a nanoscale reaction system is adaptable to executing biochemical and chemical reactions on a very small scale. To perform this reac-  
10 tion, the length of capillary would be encased within a thermocycling heat pump. The capillary tubes connecting into the length of capillary tube could deliver reagents for the polymerization chain reaction (PCR) in one of the input capillary tubes and a sample of DNA in the other  
15 input capillary. These would be combined into the single length of capillary tube and the two ends of the tube would be closed. The polymerization chain reaction would then take place as the thermocycling apparatus would then undergo the multiple cycles of timed temperature changes  
20 required for the reaction. The following description defines a device for executing this procedure.

The PCR reaction requires combination of two fluids, the PCR reaction mixture and the DNA sample. In this system, the PCR reaction mixture, containing the DNA  
25 polymerase, nucleotides, and a buffer mixture would be contained in pressurized reservoir 510. Adapter 512 is fastened onto the side of reservoir with adapter 512 bringing capillary tube 514 into fluid communication with the fluid in reservoir 510.

30 The DNA sample could be introduced through use of an injector. Injector syringe 518 would be automatically controlled by a motor 516 driven by a controller that would actuate the injector by depressing the plunger 517, introducing samples of DNA into the reaction mixture. Adapter 520 would act as an interface between  
35 macroscale syringe 518 and microscale capillary tube 522.

Capillary tube 514 and capillary tube 522 would terminate at ferrule 524 on adapter 526. The second

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member of adapter 526 contains ferrule 530. Between the ends of ferrule 524 and ferrule 530 is washer 528, shown in a sectional icon. Washer 528 has a V shaped cut out. The inner bores of capillary tube 514 and capillary tube 522 align with the top legs of the V shaped cut out. The inner bore of capillary tube 536 aligns with the bottom of the cut out. The pressure from pressurized reservoir 510 and injector 518 would drive the fluids through the system and into capillary tube section 536.

Capillary tube 536 has a distal end that terminates at ferrule 542. Affixed within ferrule 542 is a set of three fibers, capillary tube 536 and two plugged capillaries, 535 and 537. Ferrule 542 is in facing alignment with ferrule 544. Inside ferrule 544 is affixed capillary tube 538 and plugged capillaries 539 and 541. When properly oriented, the end of capillary tube 536 and the end of capillary tube 538 are in alignment and fluid can flow from into tube 538. At the opposite end of capillary tube 538 is adapter 545. Capillary 538 terminates at ferrule 552. Affixed within ferrule 552 is capillary 538 and two plugged capillaries 549 and 547. Aligned facing ferrule 552 is ferrule 554. Ferrule 554 contains two capillary tubes, 544 and 542 and one plugged capillary 543.

After capillary tube 538 is filled with the reaction mixture and DNA sample, ferrule 542 can be rotated one-third turn, which will align the relatively non-rotating ends of capillary 536 with a plugged capillary 541. The second end of capillary tube section 538 can also be sealed by rotating ferrule 554 until plugged capillaries 549 and 547 block capillary tubes 542 and 544 and plugged capillary 543 blocks capillary tube 538. Capillary tube 538 would then be sealed on both ends. Chemistry could then be performed in capillary tube 538.

Capillary tube section 538 is encased within thermal cycling apparatus 550. Apparatus 550 would then undergo temperature cycles to effect the polymerase chain reaction. When the reaction had completed, ferrule 542

could be rotated to again have capillary tubes 536 and 538 align. Ferrule 554 could be rotated so that capillary 538 aligned with capillary 544. The contents of the reaction tube could then be pumped from capillary tube 538 into capillary tube 544 which could lead to a DNA analysis apparatus. After capillary tube 538 had been emptied, ferrule 554 could be again rotated to align capillary tube 538 with capillary tube 542. At the same time, capillary 511 is aligned with capillary 514 and capillary 536 and capillary 538 through adapters 511a, 526 and 540. Capillary tube 542 leads to wash solution reservoir 560. Applying pressure on reservoir 560 will flush the reaction capillary 538, as will capillaries 536 and 514, into waste container 515 via capillary 511.

15

#### EXAMPLE 5: CAPILLARY ELECTROPHORESIS DNA DETECTION

The capillary tubes described in the present invention are adaptable to equipment for the separation and analysis of chemicals and biopolymers, such as nucleic acid sequences. In Fig. 16, one embodiment of this system is shown. Although this example shows capillary electrophoresis for a single sample, the apparatus may be combined with the apparatus of Example 3 so that multiple samples could be handled. While this example shows capillary electrophoresis, alternate embodiments encompass other separation methods, such as microbore high pressure chromatography, gas chromatography, ion chromatography and mass chromatography.

The first step in this process requires filling a capillary tube with a separation matrix. The separation matrix is kept in a pressurized reservoir 430 connected by adapter 433 to capillary tube 432, having a cross-section 432a shown in the icon above adapter 433. The end of this capillary tube is brought into fluid communication with capillary tube 438. The matrix will then flow through sample injection capillary tube 490 which is aligned with the capillary tube 438 to the end of the tube which is aligned with the end of capillary

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tube 444. See the cross sections near ferrules 443 and 445, as well as near ferrules 475 and 485. The opposite end of this tube 444b is aligned with an end of capillary tube 466 which conducts the displaced contents of tube  
5 466 to a waste receptacle 467. See cross sections 444b and 466a near ferrules 455 and 457, respectively.

After capillary tube 444 has been filled with the separation matrix, the DNA sample and denaturant are moved into sample injection capillary 490. Syringe 412  
10 controlled by controller 410 injects a fluorescently labeled DNA sample into capillary tube 414. Denaturant is introduced through capillary tube 416. The ends of these two tubes, corresponding to cross-sections 414a and 416a, terminate at ferrule 415. Abutting ferrule 415 is  
15 ferrule 417 containing single capillary 422. Between ferrules 415 and 417 is a washer 420 with a V shaped cut out. Fluid from capillary tube ends, corresponding to cross sections 414a and 416a, flow into the legs of the V and are combined at the point of the V into an end,  
20 corresponding to cross section 422a, of capillary tube 422. An alternative embodiment uses a ferrule with capillary tubes 414a and 414b recessed, as described. The sample and denaturant then flows through capillary 422 to ferrule 443 which has been rotated such that end  
25 490a is aligned with end 422b of capillary tube 422 and the combined DNA and denaturant mixture are loaded into sample loading capillary 490. Ferrule 475 terminates capillary 490 and abuts ferrule 485 associated with separation capillary 444 and waste delivery capillary  
30 497. When the sample injection capillary 490 is loaded, capillary end 490b is aligned with capillary 497a. Excess sample may be diverted into waste container 498 through waste capillary 497 from ferrule 485. If pressure injection is desired, the sample in the loading  
35 capillary 490 may also be advanced by pressure into separation capillary 444 toward ferrule 455, which, together with ferrule 457, is open to capillary 466 in communication with the waste reservoir 467. Icons 494



and 496 indicate that the loading capillary 490 may be switched between the reaction capillary 444 and a waste delivery capillary 497, leading to waste reservoir 498.

With the DNA sample and denaturant loaded into  
5 capillary tube 490, the sample is ready to be electrophoretically separated. Ferrule 443 is rotated so that end 490a aligns with end 442b of capillary tube 442. Ferrule 475 is rotated so that the loading capillary 490 communicates through ferrule 475 to the separation  
10 capillary 444 through ferrule 485. End 442a contains an electrode 440 in a reservoir 492 for introducing electric potential, i.e. voltage, into the capillary tube. The reservoir 492 is filled with a matrix which contains a conducting buffer, such as TBE (Tris, Boric acid, EDTA).  
15 At the other end of capillary tube 444, end 444b is aligned with end 464a of tube 464. This tube is also filled with a conducting buffer and terminates an electrode 470. Current will then flow from electrode 440 to electrode 470 through the buffer in capillary tube 442,  
20 through the denatured DNA sample in loading capillary 490, through the matrix in capillary tube 444 and then pass through the buffer in capillary tube 464 and into the electrode 470. The DNA will migrate through the separation matrix, with the smaller DNA fragments moving  
25 more quickly than the larger DNA fragments. DNA fragments, as they are moved by the voltage will be drawn past laser induced fluorescence apparatus 460. This apparatus provides laser light of a known frequency perpendicular to the DNA stream, causing the labeled DNA  
30 to fluoresce. The fluorescence is then detected by a detector.

After the separation and detection are complete, the sample loading capillary 490 may be purified with fluid from a wash reservoir 436 flowing under  
35 pressure through ferrule 437, through capillary 438, into loading capillary 490 and then to the waste delivery capillary 497, flowing into waste reservoir 498. Similarly, any remaining fluid in capillary 444 may be

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diverted through ferrules 455 and 457 into waste reservoir 467.

To load another sample, the loading capillary 490 is configured by alignment of ferrules 445, 443, 417 and 415 to receive fluid from sample capillary 414. An experiment may now proceed as previously described.

To replace the matrix after an experiment or series of experiments, ferrule 457 is rotated to have end 444b of capillary tube 444 align with end 466a of capillary tube 466. Ferrule 475 is rotated so that the end of capillary tube 490b aligns with end 444a of capillary tube 444. Ferrule 443 is rotated so that the end of capillary tube 490a aligns with end 438b of capillary tube 438. Ferrule 437 is rotated so that the end of capillary tube 438a aligns with end 434b of capillary tube 434. The other end 434a of capillary tube 434 is in fluid communication with wash solution in pressurized wash reservoir 436. Wash solution would then be driven through capillary 434, through capillary 438, through capillary 490, through capillary 444, and into capillary tube 466 where it would be transferred into waste reservoir 467. After washing of the matrix from the capillary tubes, the matrix could be refilled, as described above.

From the above description, it may be seen that the capillary valve, connector and router of the present invention provide a method for performing chemical reactions. The above examples shows that reactants for a chemical reaction or measurement may be placed in a plurality of capillary tubes having ends which terminate in a closely spaced pattern within a first ferrule. The opens ends of the tubes face in the same direction. Selected reactants may be merged into a single reaction capillary which is movable among the plurality of capillary tubes. The reactants can be combined by moving the reaction capillary tube among the various capillary tubes among the plurality of tubes. Alternatively, a flow conduit defined in a washer or the like placed between the plurality of capillary tubes and the single tube may

provide the desired flow channel. If the plurality of capillary tubes is arranged in a first ferrule and the single capillary tube is in a second ferrule, abutting the first ferrule, movement of one ferrule with respect to the other will bring the single capillary tube into selective communication with desired capillaries among the plurality of capillary tubes.

The preferred arrangement of capillary tubes within a ferrule is shown by the examples of Fig. 17a-17e. Fig. 17a shows an outer ring of fifteen capillaries surrounding an intermediate ring of nine capillaries which, in turn, surrounds an inner ring of three capillaries. Fig. 17b shows an outer ring of twelve capillaries surrounding an intermediate ring of six capillaries which, in turn, surrounds a single capillary. Fig. 17c shows an outer ring of nine capillaries surrounding an inner ring of three capillaries. Fig. 17d shows an outer ring of six capillaries surrounding a single capillary. Fig. 17e shows a rectangular array of capillaries. In each case, capillaries are tangent to other capillaries. To achieve tangency, the capillaries are preferably the same size so that close packing can be achieved. Fibers are interchangeable with capillaries but, if difficulty is encountered in obtaining optical fibers which are the same size as capillaries, plugged capillaries are used. The geometries illustrated in Figs. 17a-17e are illustrative examples of close packing. Other geometries exist.

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## Claims

1. A capillary switch or valve comprising:  
a first cylindrical, rotatable ferrule having a  
5 first number of fibers in fixed positions therein, at  
least one of the fibers being a capillary tube;  
a second cylindrical, rotatable ferrule having  
a second number of fibers in fixed positions therein, at  
least one of the fibers being a capillary tube; and  
10 a fastener joining the first and second  
ferrules in a manner bringing the first and second  
ferrules into abutment wherein a capillary tube in the  
first ferrule may be selectively moved relative to the  
second ferrule.  
15
2. The apparatus of claim 1 wherein said first number is  
three and said fibers of the first ferrule are mutually  
tangent in cross section.  
20
3. The apparatus of claim 2 wherein said second number  
is three and said fibers of the second ferrule are  
mutually tangent.  
25
4. The apparatus of claim 1 wherein one or more of the  
fibers in each of the first and second ferrules is a  
fiber optical fiber.  
30
5. The apparatus of claim 4 wherein a light source and  
an optical detector are associated with at least one of  
the optical fibers.  
35

6. The apparatus of claim 1 further comprising a motor operatively connected to move one of the ferrules by a selectable amount.

5

7. The apparatus of claim 1 further comprising a plurality of capillaries in one of said ferrules connected at an end distal to the ferrule to reagent reservoirs.

10

8. The apparatus of claim 1 further comprising a plurality of capillaries in one of said ferrules connected at an end distal to the ferrule to samples.

15

9. The apparatus of claim 1 wherein a capillary in one of said ferrules is connected at an end distal to the ferrule to a syringe.

20

10. The apparatus of claim 9 wherein said syringe is responsive to control by electrical signals.

25

11. The apparatus of claim 1 further comprising a plurality of capillaries in one of said ferrules connected at an end distal to the aligned end of the ferrule to a plurality of reagent delivery sites.

30

12. The apparatus of claim 1 further defined by rotational position of the first and second ferrules wherein capillaries in the first and second ferrules are not aligned by rotation of the first ferrule relative to the second ferrule thereby blocking fluid communication between capillaries in the first and second ferrules.

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13. The apparatus of claim 1 wherein one of the ferrules has one capillary tube and the other ferrule has a plurality of capillary tubes whereby the one capillary can communicate fluid to a plurality of capillary tubes by rotation of the one ferrule relative to the other, thereby routing fluid from the one capillary tube in one ferrule to another capillary tube in the other ferrule.

10

14. The apparatus of claim 1 further comprising a thin member having a fluid channel therein placed between the first and second ferrules, the fluid channel defining a manifold whereby fluid from a single capillary tube in one ferrule can communicate with a plurality of capillary tubes in the other ferrule.

20

15. The apparatus of claim 1 wherein the fibers in the first ferrule are the same diameter as fibers in the second ferrule.

25

16. The apparatus of claim 1 wherein at least one of the fibers in the first ferrule is a plugged capillary tube.

30

17. A capillary connector comprising:

a first set of one or more fibers, at least one being a capillary tube;

5 a first rotatable ferrule having a first and a second end with said first set of fibers received through said first end, said first set of fibers fixedly and non-rotatably attached within said first ferrule at said second end;

10 a second set of one or more fibers, at least one of said one or more fibers being a capillary tube;

a second rotatable ferrule having a first and a second end with said second set of fibers received through said first end, said second set of fibers affixedly and non-rotatably attached within said second ferrule at said second end; and

15 an adapter device for receiving said first and second ferrules whereby said second end of said first ferrule and said second end of said second ferrule are held in mutually joined alignment.

20

18. The capillary connector according to claim 17 wherein said adapter device comprises a pair of joined sleeves, one sleeve associated with each ferrule, the ends of said first ferrule and said second ferrule abutting in mutually biased alignment.

25

19. The capillary connector according to claim 17 further comprising:

30

a first flexible strain relief boot attached to said first end of said first ferrule whereby said first set of one or more fibers is protected from snapping at said first end of said first ferrule; and

35

a second flexible strain relief boot attached to said first end of said second ferrule whereby said second set of one or more fibers is protected from snapping at said first end of said second ferrule.

20. The capillary connector of claim 16 wherein said first set of one or more fibers comprises three fibers, at least one of which is a capillary tube and at least one of which is a member of the plugged capillary tube and a fiber optic fiber.

21. The capillary connector of claim 17 wherein said second set of one or more fibers comprises three fibers, two of which are capillary tubes and one of which is a plugged capillary tube.

22. The capillary connector of claim 21 further comprising:

a washer located between said first and second ferrules, said washer having a cut out pattern for channeling fluid from said one capillary tube contained in said first ferrule into said two capillary tubes located in said second ferrule.

23. The capillary connector of claim 21 wherein said two capillary tubes in said second ferrule are slightly recessed from said second end of said second ferrule, thereby allowing fluid communication with said one capillary tube located in said first ferrule when the ends of said first and second ferrules are in mutually biased alignment and are in a predetermined orientation.

24. The capillary connector of claim 17 wherein said first set of one or more fibers comprises seven fibers, at least one of which is a capillary tube. and where in the fibers are packed such that six of said seven fibers radially surround a seventh fiber.



25. The capillary connector of claim 16 wherein said connector includes an alignment indicator, indicating the orientation of the said first set of fibers in relation to said second set of fibers.

5

26. The capillary connector according to claim 16 further comprising:

10 a motor operatively associated with said first ferrule and capable of rotating said first ferrule relative to said second ferrule; and

a controller for controlling said motor and allowing selectable alignments of said first ferrule relative to said second ferrule.

15

27. The apparatus of claim 16 further comprising:

a first fiber optic fiber included in the first set of one or more fibers;

20 a second fiber optic fiber included in the second set of one or more fibers;

a light source at the distal end of said first fiber optic fiber for introducing light into said first fiber optic fiber; and

25 a light detector attached to the distal end of said second fiber optic fiber whereby when light is introduced into said first fiber optic fiber and detected at the end of said second fiber optic fiber the fibers would be in alignment and other fibers positioned about  
30 said first and second fiber optic fibers would also be in alignment.

28. The apparatus of claim 27 wherein said light source  
35 is a semiconductor device.

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29. A capillary connector comprising:

a first capillary tube having a first diameter;

5 a first rotatable ferrule having a first and a second end with said capillary tube received through said first end of said ferrule and fixedly and non-rotatably attached therein;

a second capillary having a diameter equal to said first diameter of said first capillary tube;

10 a second rotatable ferrule having a first and a second end with said second capillary received through said first end of said ferrule, said second capillary fixedly and non-rotatably attached within said second ferrule, said second capillary having an end aligned with said second end of said second ferrule; and

15 an attachment device for receiving said first and second ferrules whereby said second end of said first ferrule and said second end of said second ferrule are held in mutually joined alignment.

20

30. The connector of claim 29 further comprising:

an alignment indicator associated with said second ferrule whereby the orientation of said second tube within said second ferrule could be indicated.

25

31. A capillary connector according to claim 29 wherein said attachment device is comprised of:

a first sleeve surrounding said first ferrule;

30 a second sleeve surrounding said second ferrule; and

an adapter comprising a first attachment device connected to said first sleeve and a second attachment device connected to said second sleeve bringing the ends  
35 of said first ferrule and said second ferrule into mutually biased alignment.

32. A capillary connector according to claim 29 further comprising:

5 a first flexible strain relief boot attached to said first end of said first ferrule whereby said first set of one or more fibers is protected from snapping at said first end; and

10 a second flexible strain relief boot attached to said first end of said second ferrule whereby said second set of one or more fibers is protected from snapping at said first end of said second ferrule.

33. A capillary connector comprising:

15 a set of one or more fibers with at least one of said one or more fibers being a capillary tube;

20 a rotatable ferrule having a first and second end with the set of fibers entering said first end of said sleeve and said set fixedly and non-rotatably attached within said ferrule and with said set of one or more fibers terminating at a level surface on the second end of said first ferrule; and

an attachment device annularly surrounding said ferrule.

25

34. A capillary connector according to claim 33 further comprising:

30 a flexible strain relief boot attached to said first end of said ferrule whereby said set of one or more fibers is protected from snapping at said first end.

35. The apparatus of claim 33 further comprising:

35 an alignment indicator associated with said ferrule whereby the orientation of said set of one or more fibers within said ferrule could be indicated.

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36. A capillary connector system for interfacing a macroscale fluidic device to a capillary comprising:  
a capillary-like member attached to a macroscale fluidic device, joined by an adapter to a first end of a first capillary tube;  
a first cylindrical, rotatable ferrule joined to a second end of the first capillary tube;  
a second cylindrical, rotatable ferrule having a second number of fibers in fixed positions therein, at least one of the fibers being a capillary tube; and  
a fastener joining the first and second ferrules in a manner bringing the first and second ferrules into abutment wherein the capillary tubes in each of the ferrules may be mutually aligned or not aligned by rotation of the first ferrule relative to the second ferrule.

37. The capillary connector system of claim 36 wherein said macroscale fluidic device is a syringe.

38. The capillary connector system of claim 37 wherein said syringe is motor driven.

39. The capillary connector system of claim 36 wherein said second number of fibers comprises a plurality of capillaries, the first capillary tube in the first ferrule being positioned to selectively come into fluidic communication with each of said plurality of capillaries by rotation of the first ferrule relative to the second ferrule.

40. A capillary connector system for push-pull loading and unloading of micro-wells comprising:

5 a first branching valve having a first pump connected to the input of the valve and having first and second output capillaries, the first output capillary connected to a fluid reservoir and the second output capillary connected to a storage capillary;

10 a second branching valve connected in reverse orientation relative to the first branching valve with a first input capillary connected to the storage capillary, a second input capillary in communication with a plurality of wells and an output capillary forming a storage section; and

15 a third branching valve having an input capillary connected to the output capillary of the second branching valve and an output capillary connected to a second pump,

20 whereby fluid may be pumped from the reservoir to the storage capillaries and then to the wells by push-pull action of the pumps.

25 41. A capillary connector system for detection of a target substance in a liquid sample by capillary electrophoresis comprising:

30 a first branching valve having a first input of a target sample associated with a sample pump and a sample input capillary, a second input of an electrophoretic solution capillary associated with a first electrode and a third input of a separation matrix capillary, said inputs selectively valved to the first end of a capillary tube having a target sample detector associated therewith; and

35

-44-

a second branching valve having as an input a second end of the capillary tube having a target sample detector associated therewith and having as an output an electrophoretic solution capillary associated with a second electrode, establishing an electric current relative to the first electrode, and a flow path capillary for excess fluid wherein target sample may be pumped by the sample pump in the current path between the first and second electrodes.

10

42. The connector system of claim 41 wherein each branching valve comprises:

a first cylindrical, rotatable ferrule having a first number of capillaries in fixed positions therein;

a second cylindrical, rotatable ferrule having a second number of capillaries in fixed positions therein; and

a fastener joining the first and second ferrules in a manner bringing the first and second ferrules into abutment wherein the capillary tubes in each of the ferrules may be mutually aligned or not aligned by rotation of the first ferrule relative to the second ferrule.

25

43. A capillary connector system for combination of two fluids comprising:

a manifold valve having a first input of a sample material associated with a sample pump and a sample input capillary, a second input of a fluid reagent solution in a reagent capillary, said inputs combined in a manifold to the first end of a capillary tube; and

an on-off valve connected to the second end of the capillary tube having an output capillary carrying combined fluids.

44. A method for performing chemical reactions comprising:

- 5 providing reactants for a chemical reaction in a plurality of capillary tubes having ends terminating at closely spaced locations and facing the same direction;
- merging the reactants in at least some of the plurality of capillary tubes into a single reaction capillary tube having an open end in selective fluid communication with said closely spaced locations; and
- 10 removing the contents of the reaction capillary tube after a chemical reaction has occurred.

45. The method of claim 44 wherein the single reaction capillary tube faces the plurality of capillary tubes facing the same direction.

15

46. The method of claim 44 further defined by connecting at least one capillary tube among said plurality of capillary tubes to a macroscale apparatus.

20

47. The method of claim 44 further defined by packing said plurality of capillary tubes in a closely packed geometric configuration.

25

48. The method of claim 44 further defined by providing a test capillary tube downstream of the reaction capillary tube, the test capillary tube having optical apparatus measuring the contents of the reaction capillary tube.

30

35

49. The method of claim 44 further defined by providing a test capillary tube downstream of the reaction capillary tube, the test capillary tube having electrical apparatus measuring the contents of the reaction capillary tube.

50. The method of claim 44 further defined by providing a second reaction capillary tube downstream of the reaction capillary tube, the second reaction capillary tube having thermal apparatus cycling the temperature of the contents of the reaction capillary tube.

51. The method of claim 44 wherein the plurality of capillary tubes terminate in a first ferrule and the single reaction capillary tube terminates in a second ferrule abutting the first ferrule, the method further defined by moving the first ferrule relative to the second ferrule thereby bringing the reaction capillary into fluid communication with a selected one of the plurality of capillary tubes.

52. An arrangement of capillary tubes for transferring fluid to at least one desired capillary tube comprising:  
a first ferrule having a plurality of capillary tubes terminating with open ends facing in the same direction, the tubes closely packed in a geometric close packing pattern; and  
a second ferrule having a capillary tube with an open end located in close proximity and facing the open ends of the plurality of capillary tubes and being moveable therewith in selective fluidic communication with at least one of the plurality of capillary tubes.



53. The arrangement of claim 52 wherein said geometric close packing pattern comprises an outer ring of 15 capillaries surrounding an intermediate ring of 9 capillaries surrounding an inner ring of 3 capillaries.

5

54. The arrangement of claim 52 wherein said geometric close packing pattern comprises an outer ring of 12 capillaries surrounding an intermediate ring of 6 capillaries surrounding an inner single capillary.

10

55. The arrangement of claim 52 wherein said geometric close packing pattern comprises an outer ring of 9 capillaries surrounding an inner ring of 3 capillaries.

15

56. The arrangement of claim 52 wherein said geometric close packing pattern comprises an outer ring of 6 capillaries surrounding an inner single capillary.

20

57. The arrangement of claim 52 wherein said geometric close packing pattern comprises a rectangular array of capillaries.

25

58. A method of depositing material on microtiter plates comprising:

30

providing a supply of fluid for deposition on microtiter plates in a macroscale pump connected to an output capillary; and

35

providing a plurality of connected capillary tubes extending between the output capillary and a microtiter plate through capillary valves and routers.

59. The method of claim 58 further defined by providing a second pump connected to a second output capillary for push-pull pumping of fluid in at least some of the connected capillary tubes.

5

60. The method of claim 58 further defined by moving the microtiter plate to bring multiple wells into fluid communication with the connected capillary tubes.

## AMENDED CLAIMS

[received by the International Bureau on 22 February 1999 (22.02.99);  
original claims 1, 17, 20, 25-27, 29, 32 and 42 amended;  
remaining claims unchanged (7 pages)]

1. A capillary switch or valve comprising:
  - a first cylindrical, rotatable ferrule having a  
5 first number of fibers in fixed positions therein, at  
least one of the fibers being a capillary tube;  
a second cylindrical, rotatable ferrule having  
a second number of fibers in fixed positions therein, at  
least one of the fibers being a capillary tube; and  
10 a fastener for removably coupling the first and  
second ferrules in a manner bringing the first and second  
ferrules into abutment such that either ferrule may be  
rotated in relation to the other, wherein a capillary  
tube in the first ferrule may be selectively moved  
15 relative to the second ferrule such that the capillary in  
the first ferrule may be brought into fluid communication  
with the capillary in the second ferrule.
- 20 2. The apparatus of claim 1 wherein said first number is  
three and said fibers of the first ferrule are mutually  
tangent in cross section.
- 25 3. The apparatus of claim 2 wherein said second number  
is three and said fibers of the second ferrule are  
mutually tangent.
- 30 4. The apparatus of claim 1 wherein one or more of the  
fibers in each of the first and second ferrules is a  
fiber optical fiber.
- 35 5. The apparatus of claim 4 wherein a light source and  
an optical detector are associated with at least one of  
the optical fibers.

17. A capillary connector comprising:

a first set of one or more fibers, at least one being a capillary tube;

5 a first rotatable ferrule having a first and a second end with said first set of fibers received through said first end, said first set of fibers fixedly and non-rotatably attached within said first ferrule at said second end;

10 a second set of one or more fibers, at least one of said one or more fibers being a capillary tube;

a second rotatable ferrule having a first and a second end with said second set of fibers received through said first end, said second set of fibers affixedly and non-rotatably attached within said second ferrule at said second end; and

15 an adapter device for removably receiving said first and second ferrules whereby said second end of said first ferrule and said second end of said second ferrule are held in mutually joined alignment.

20

18. The capillary connector according to claim 17 wherein said adapter device comprises a pair of joined sleeves, one sleeve associated with each ferrule, the ends of said first ferrule and said second ferrule abutting in mutually biased alignment.

19. The capillary connector according to claim 17 further comprising:

30 a first flexible strain relief boot attached to said first end of said first ferrule whereby said first set of one or more fibers is protected from snapping at said first end of said first ferrule; and

35 a second flexible strain relief boot attached to said first end of said second ferrule whereby said second set of one or more fibers is protected from snapping at said first end of said second ferrule.

20. The capillary connector of claim 17 wherein said  
first set of one or more fibers comprises three fibers,  
at least one of which is a capillary tube and at least  
one of which is a member of the plugged capillary tube  
5 and a fiber optic fiber.

21. The capillary connector of claim 17 wherein said  
second set of one or more fibers comprises three fibers,  
10 two of which are capillary tubes and one of which is a  
plugged capillary tube.

22. The capillary connector of claim 21 further  
15 comprising:  
a washer located between said first and second  
ferrules, said washer having a cut out pattern for  
channeling fluid from said one capillary tube contained  
in said first ferrule into said two capillary tubes  
20 located in said second ferrule.

23. The capillary connector of claim 21 wherein said two  
capillary tubes in said second ferrule are slightly  
25 recessed from said second end of said second ferrule,  
thereby allowing fluid communication with said one  
capillary tube located in said first ferrule when the  
ends of said first and second ferrules are in mutually  
biased alignment and are in a predetermined orientation.  
30

24. The capillary connector of claim 17 wherein said  
first set of one or more fibers comprises seven fibers,  
at least one of which is a capillary tube, and where in  
35 the fibers are packed such that six of said seven fibers  
radially surround a seventh fiber.

25. The capillary connector of claim 17 wherein said connector includes an alignment indicator, indicating the orientation of the said first set of fibers in relation to said second set of fibers.

5

26. The capillary connector according to claim 17 further comprising:

10 a motor operatively associated with said first ferrule and capable of rotating said first ferrule relative to said second ferrule; and

a controller for controlling said motor and allowing selectable alignments of said first ferrule relative to said second ferrule.

15

27. The apparatus of claim 17 further comprising:

a first fiber optic fiber included in the first set of one or more fibers;

20 a second fiber optic fiber included in the second set of one or more fibers;

a light source at the distal end of said first fiber optic fiber for introducing light into said first fiber optic fiber; and

25 a light detector attached to the distal end of said second fiber optic fiber whereby when light is introduced into said first fiber optic fiber and detected at the end of said second fiber optic fiber the fibers would be in alignment and other fibers positioned about  
30 said first and second fiber optic fibers would also be in alignment.

28. The apparatus of claim 27 wherein said light source  
35 is a semiconductor device.

29. A capillary connector comprising:

a first capillary tube having a first diameter;

a first rotatable ferrule having a first and a second end with said capillary tube received through said first end of said ferrule and fixedly and non-rotatably attached therein;

a second capillary having a diameter equal to said first diameter of said first capillary tube;

a second rotatable ferrule having a first and a second end with said second capillary received through said first end of said ferrule, said second capillary fixedly and non-rotatably attached within said second ferrule, said second capillary having an end aligned with said second end of said second ferrule; and

an attachment device for removably receiving said first and second ferrules whereby said second end of said first ferrule and said second end of said second ferrule are held in mutually joined alignment.

20

30. The connector of claim 29 further comprising:

an alignment indicator associated with said second ferrule whereby the orientation of said second tube within said second ferrule could be indicated.

25

31. A capillary connector according to claim 29 wherein said attachment device is comprised of:

a first sleeve surrounding said first ferrule;

a second sleeve surrounding said second ferrule; and

an adapter comprising a first attachment device connected to said first sleeve and a second attachment device connected to said second sleeve bringing the ends of said first ferrule and said second ferrule into mutually biased alignment.

35

32. A capillary connector according to claim 29 further comprising:

5 a first flexible strain relief boot attached to said first end of said first ferrule whereby said first set of one or more fibers is protected from snapping at said first end; and

10 a second flexible strain relief boot attached to said first end of said second ferrule whereby said second set of one or more fibers is protected from snapping at said first end of said second ferrule.

33. A capillary connector comprising:

15 a set of one or more fibers with at least one of said one or more fibers being a capillary tube;

a rotatable ferrule having a first and second end with the set of fibers entering said first end of said sleeve and said set fixedly and non-rotatably attached within said ferrule and with said set of one or  
20 more fibers terminating at a level surface on the second end of said first ferrule; and

a removable attachment device annularly surrounding said ferrule.

25

34. A capillary connector according to claim 33 further comprising:

30 a flexible strain relief boot attached to said first end of said ferrule whereby said set of one or more fibers is protected from snapping at said first end.

35. The apparatus of claim 33 further comprising:

35 an alignment indicator associated with said ferrule whereby the orientation of said set of one or more fibers within said ferrule could be indicated.



a second branching valve having as an input a second end of the capillary tube having a target sample detector associated therewith and having as an output an electrophoretic solution capillary associated with a second electrode, establishing an electric current relative to the first electrode, and a flow path capillary for excess fluid wherein target sample may be pumped by the sample pump in the current path between the first and second electrodes.

10

42. The connector system of claim 41 wherein each branching valve comprises:

a first cylindrical, rotatable ferrule having a first number of capillaries in fixed positions therein;

a second cylindrical, rotatable ferrule having a second number of capillaries in fixed positions therein; and

a fastener for removably coupling the first and second ferrules in a manner bringing the first and second ferrules into abutment such that either ferrule may be rotated in relation to the other, wherein the capillary tubes in each of the ferrules may be mutually aligned or not aligned by rotation of the first ferrule relative to the second ferrule such that the capillary in the first ferrule may be brought into fluid communication with the capillary in the second ferrule.

30

43. A capillary connector system for combination of two fluids comprising:

a manifold valve having a first input of a sample material associated with a sample pump and a sample input capillary, a second input of a fluid reagent solution in a reagent capillary, said inputs combined in a manifold to the first end of a capillary tube; and

## STATEMENT UNDER ARTICLE 19

In amended independent claims 1, 17, 29, 32 and 42, the claims have been amended to claim a fastener that removably couples ferrules encasing capillary tube ends. Claim 1 has been further amended to more precisely claim the ability of the ferrules of the claimed device to move in relation to each other. Claims 20 and 25-27 have been amended to correct an error in numbering.

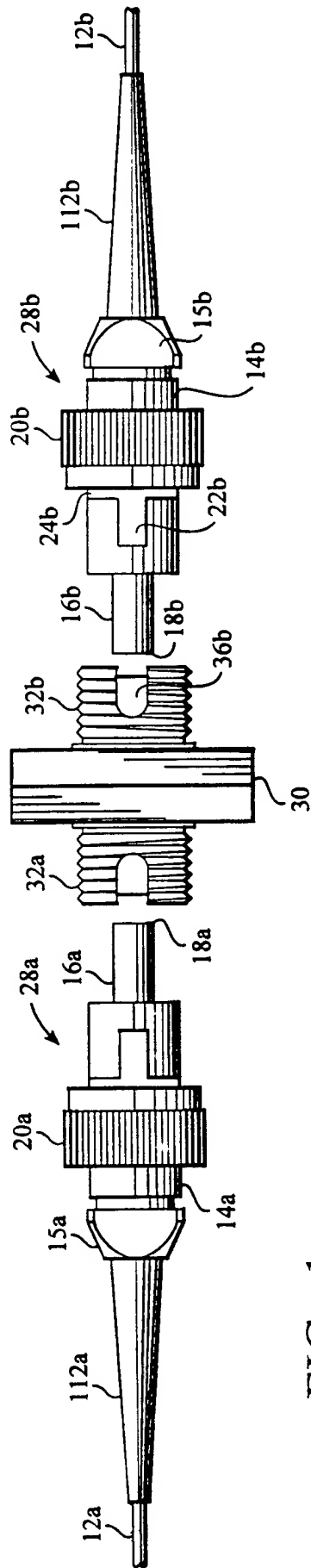


FIG. 1

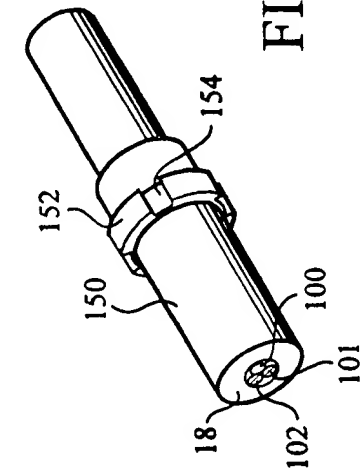


FIG. 7

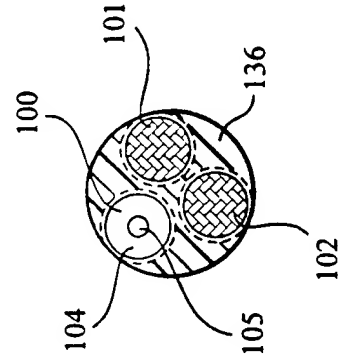
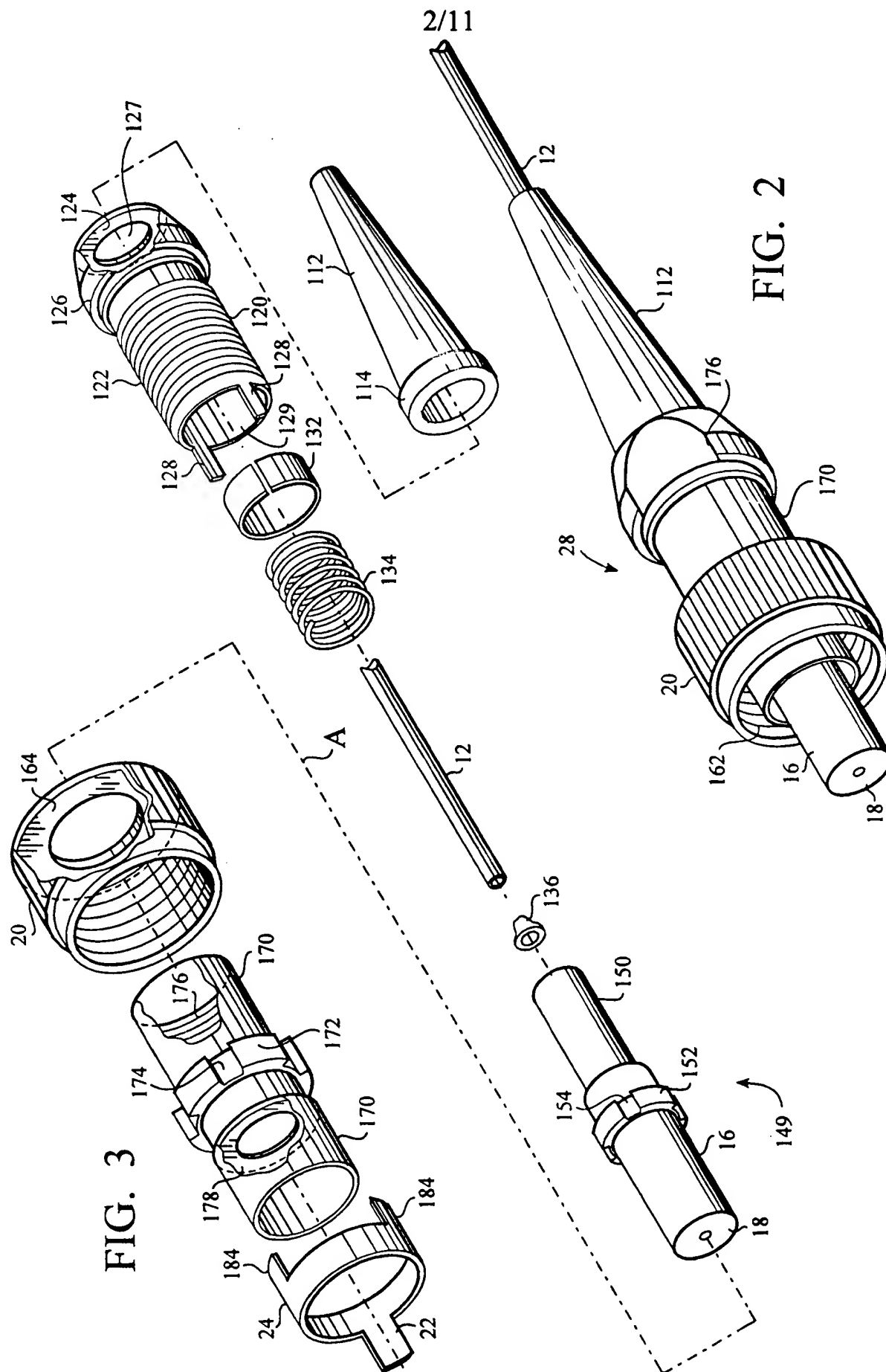


FIG. 8



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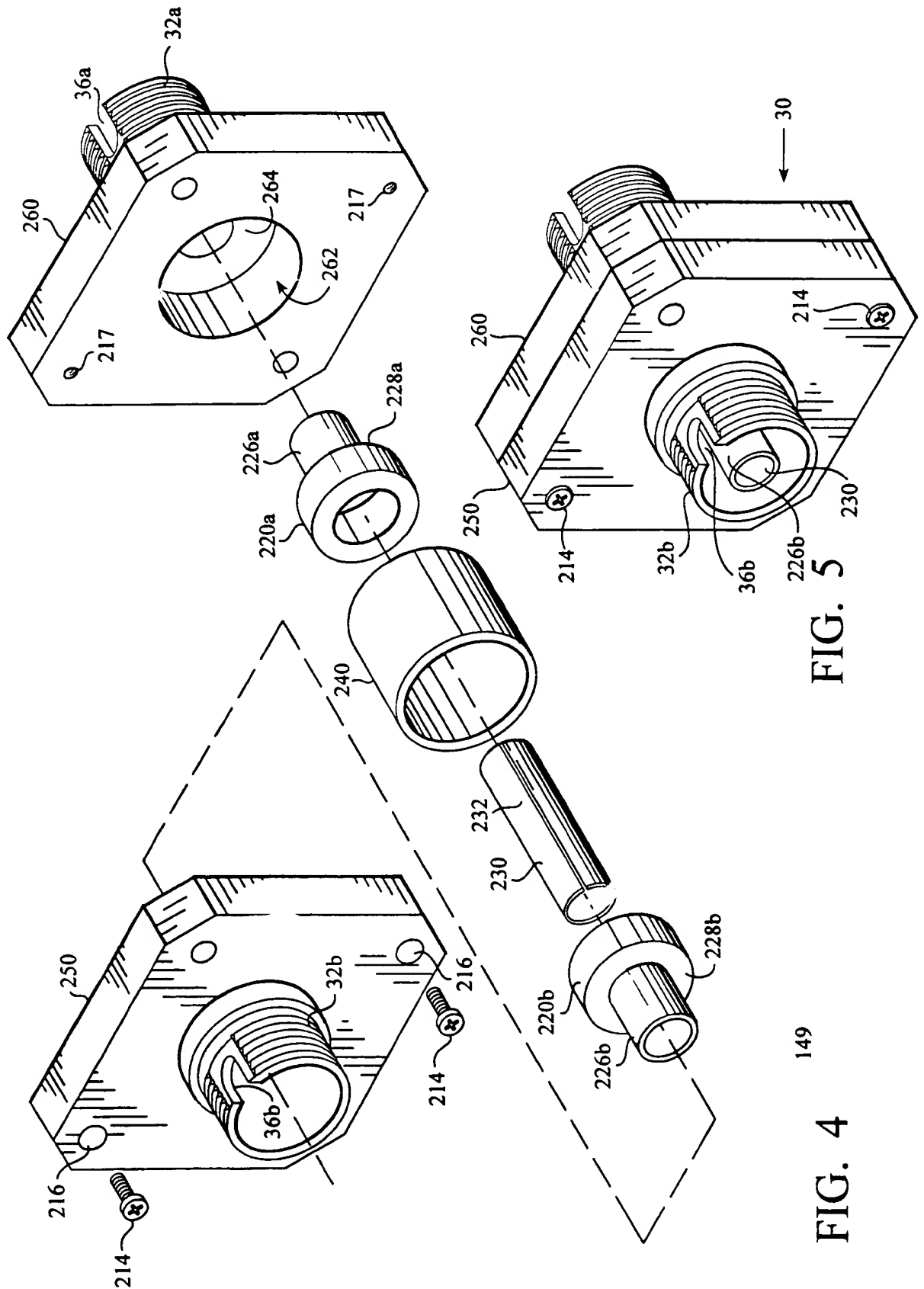


FIG. 5

FIG. 4

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FIG. 11A

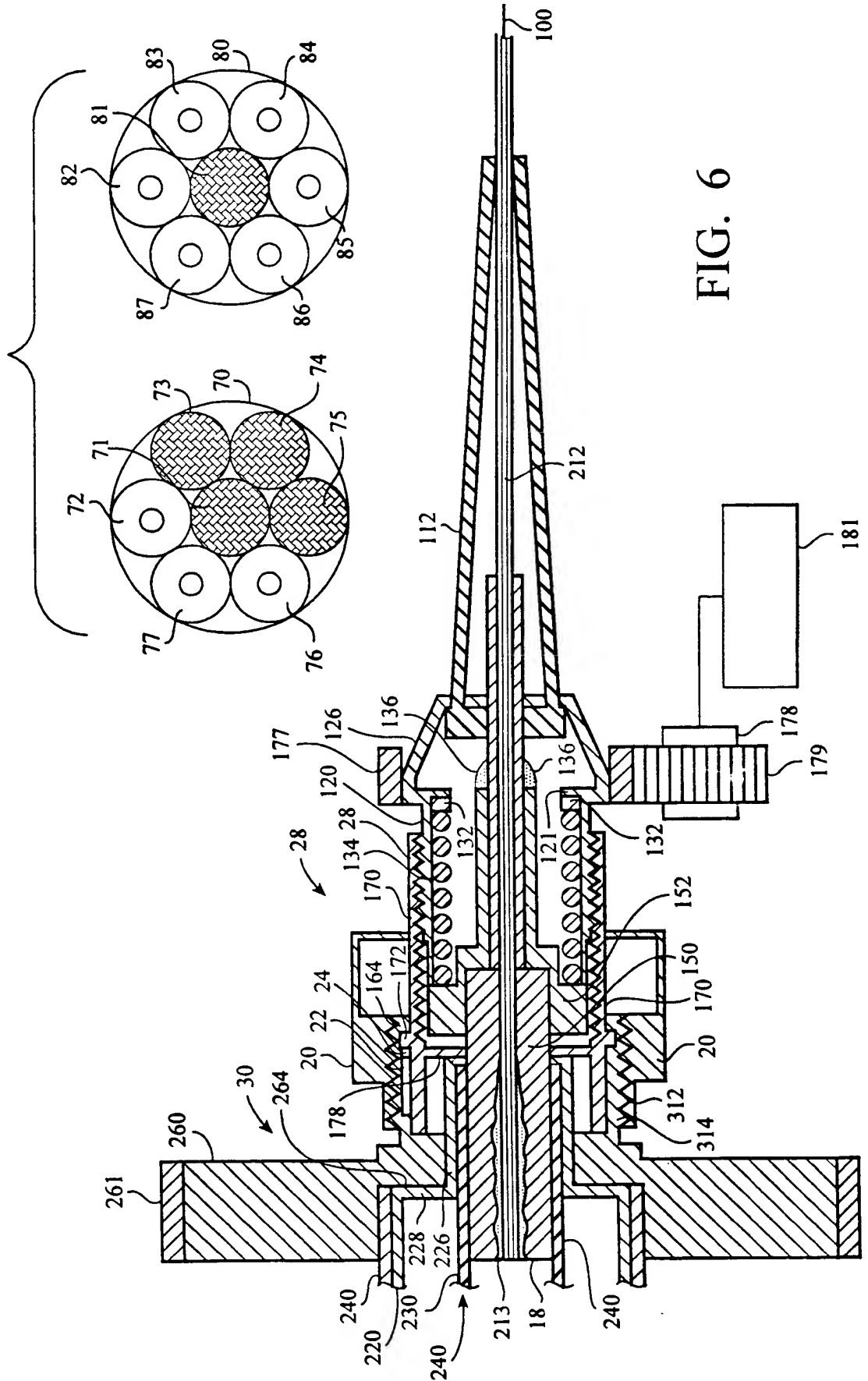


FIG. 6

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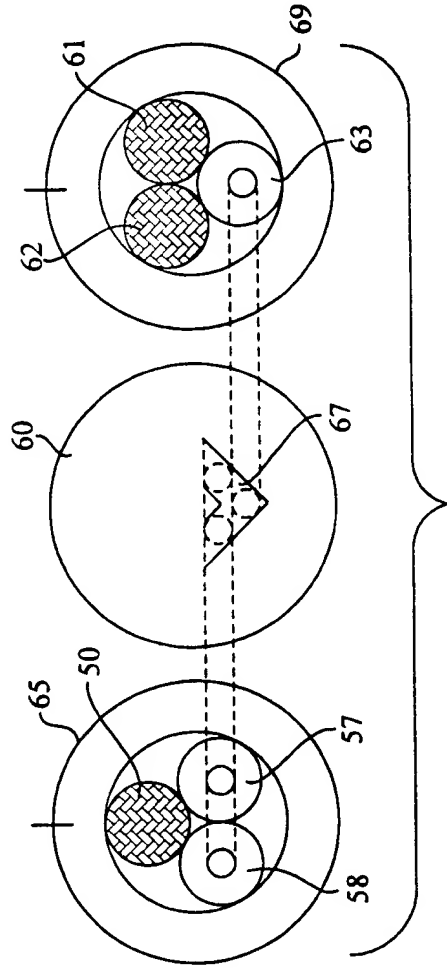


FIG. 10

FIG. 11

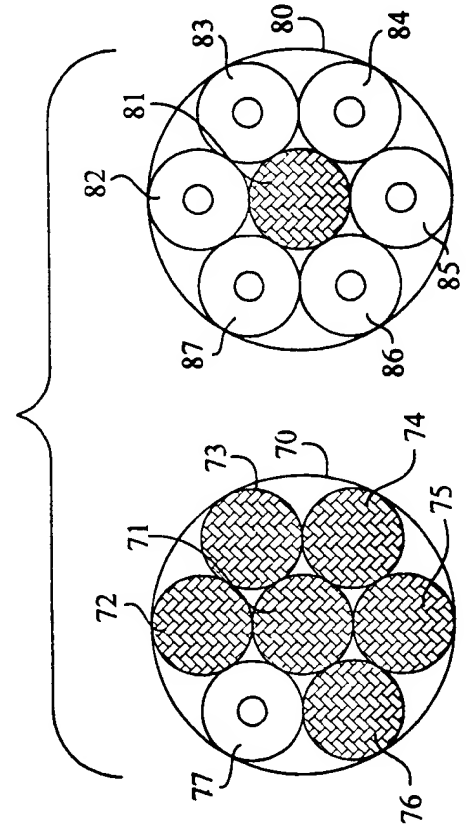


FIG. 9A

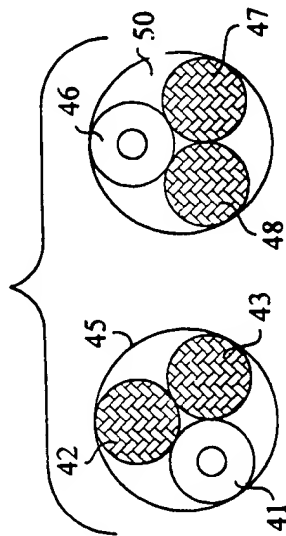
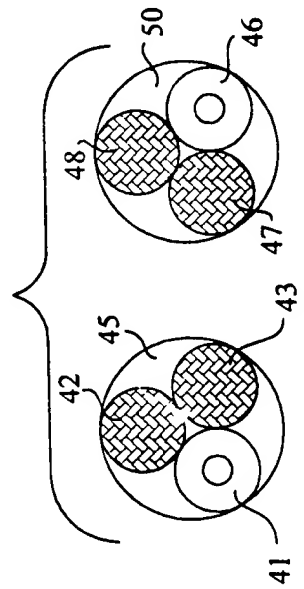


FIG. 9B



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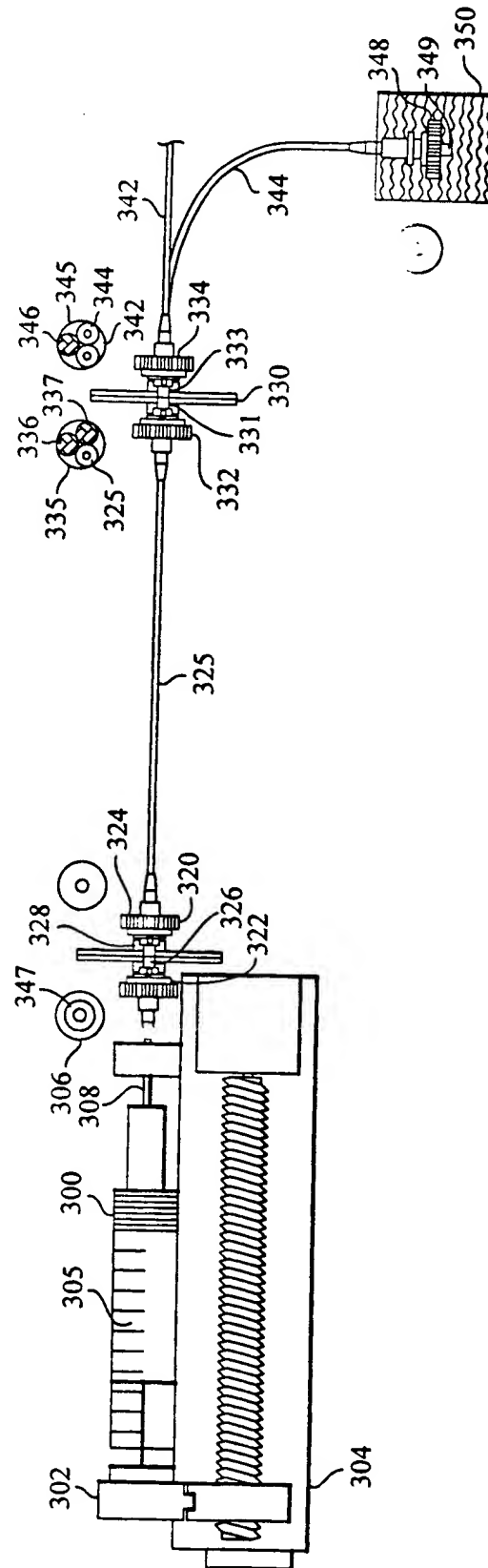


FIG. 12



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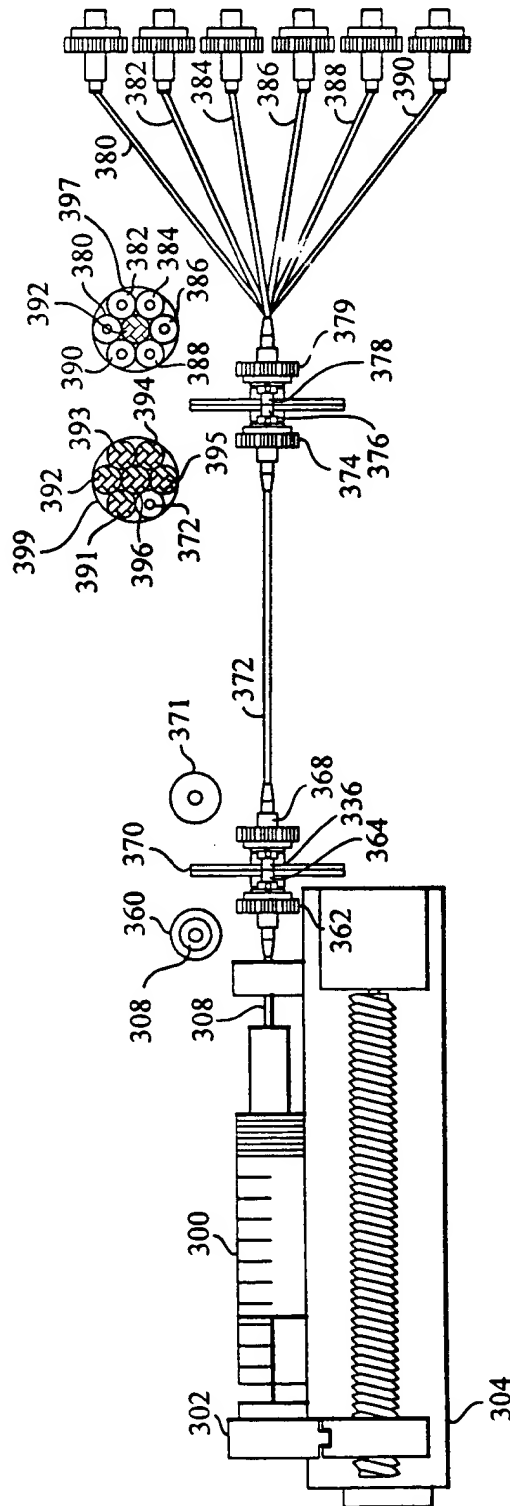


FIG. 13

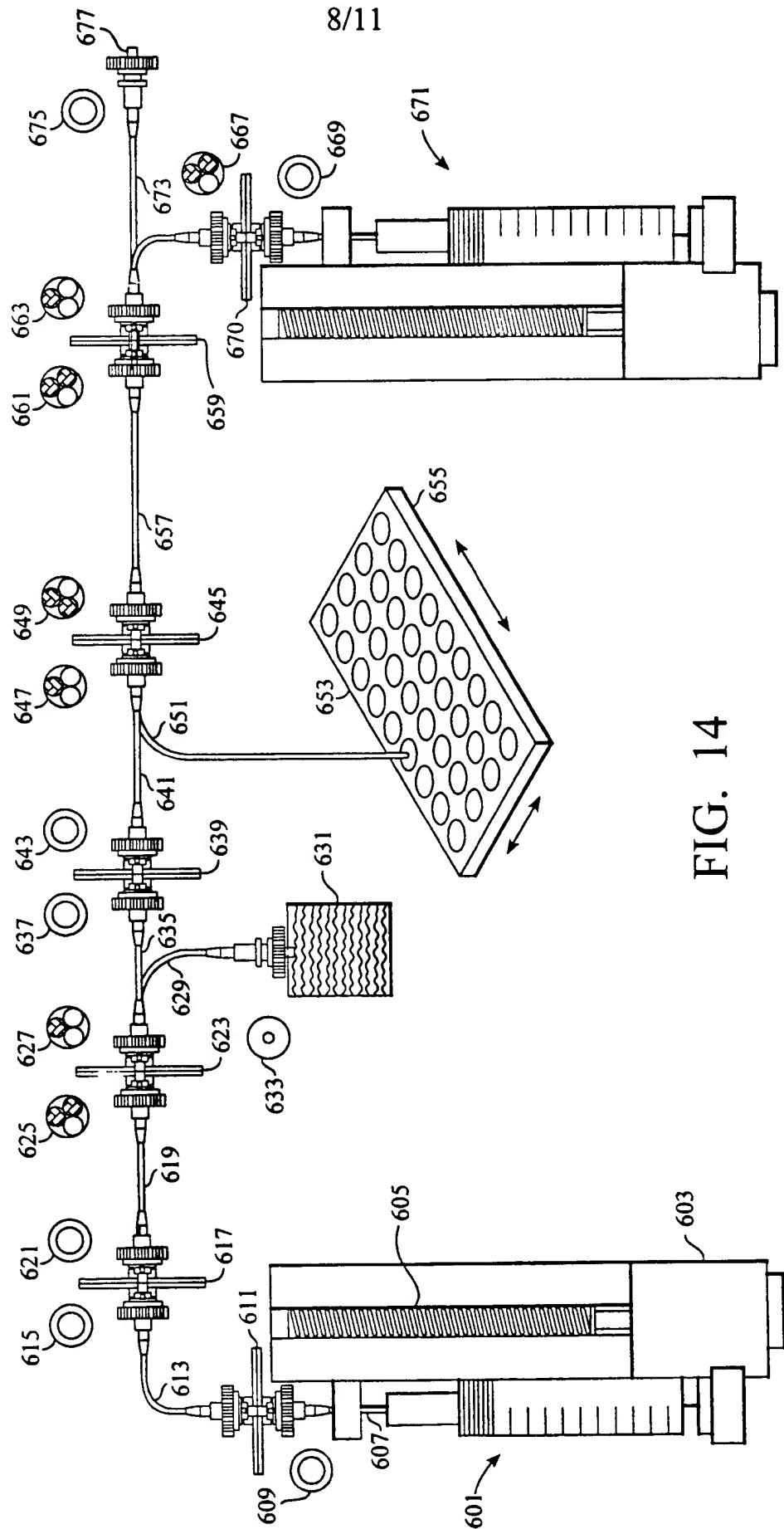


FIG. 14

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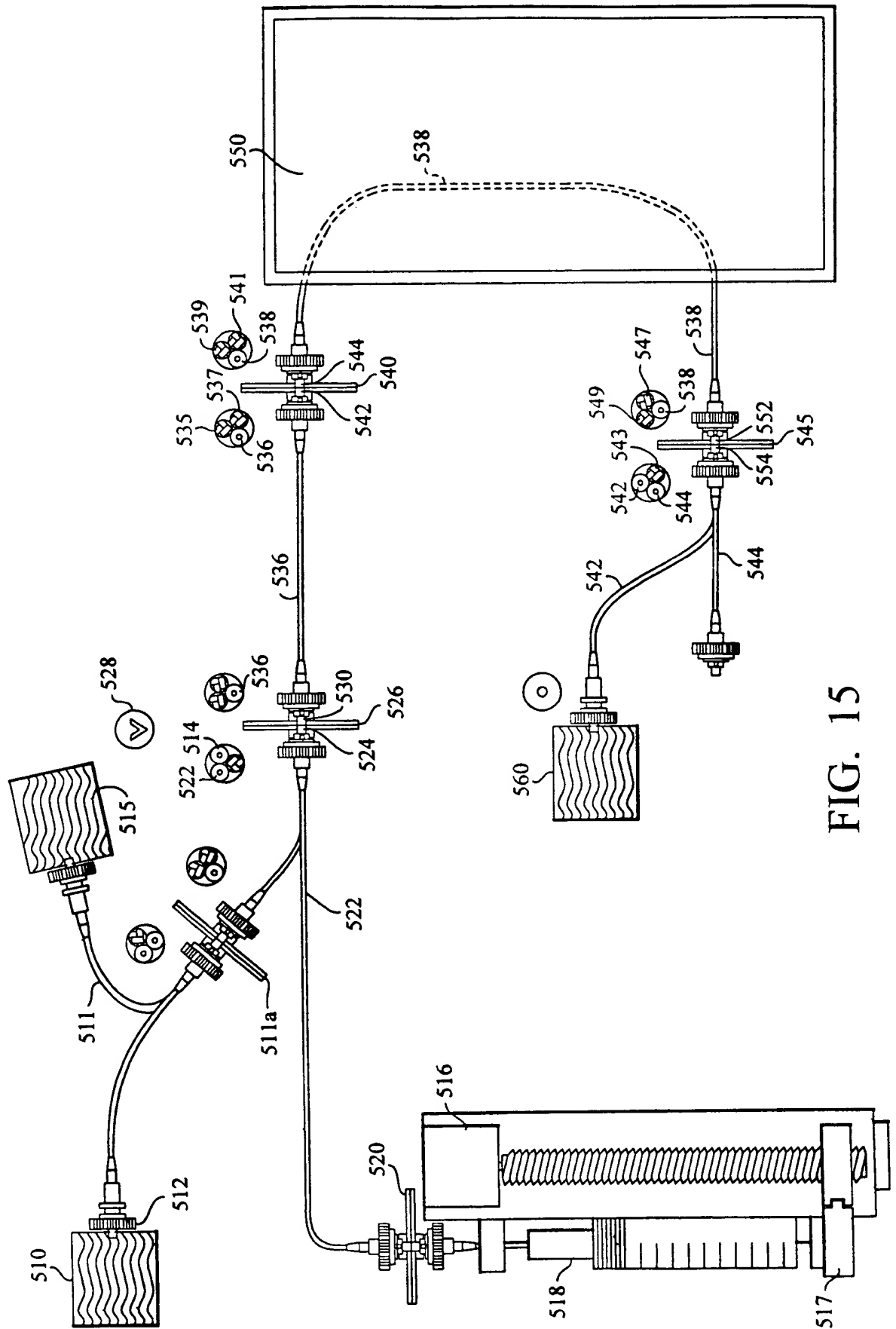


FIG. 15

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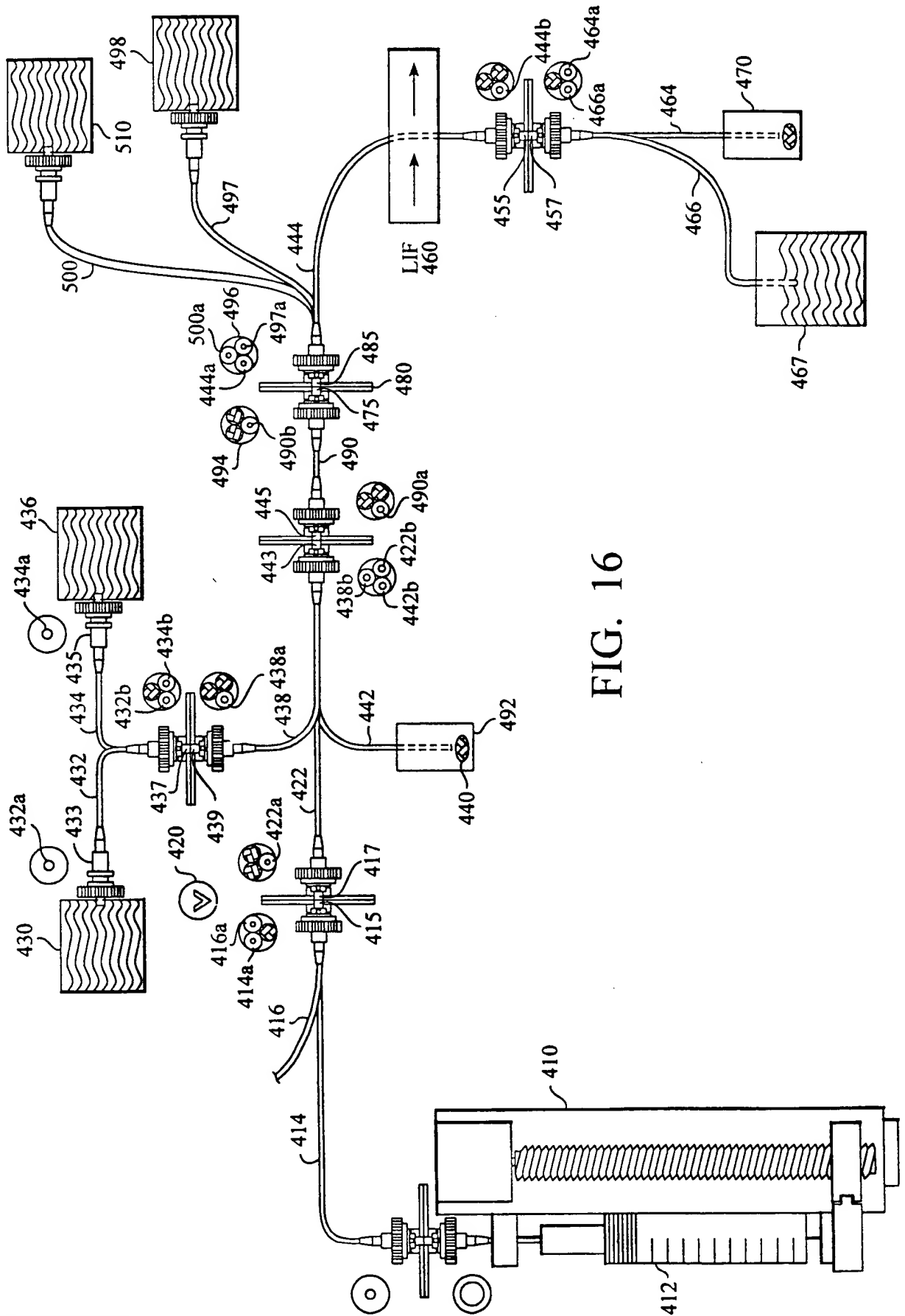


FIG. 16

11/11

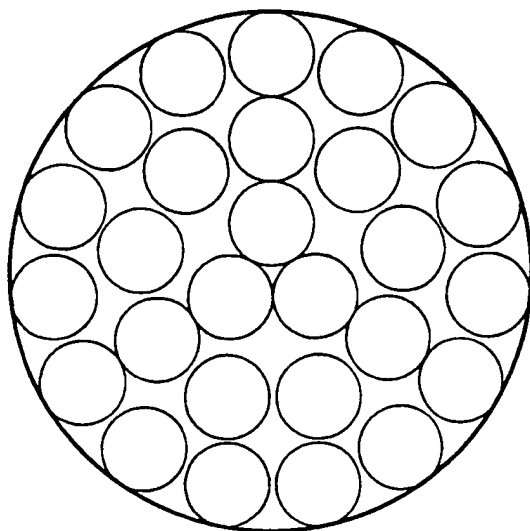


FIG. 17a

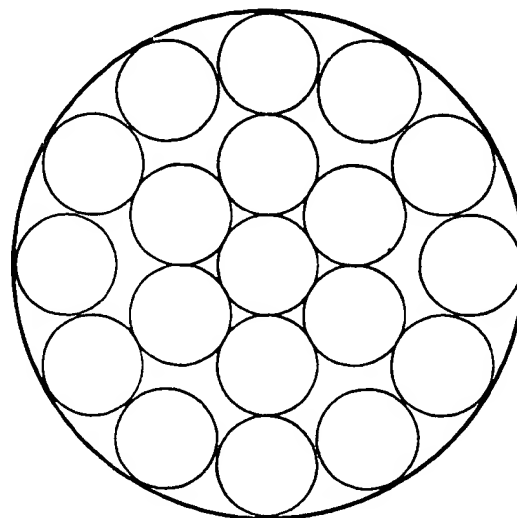


FIG. 17b

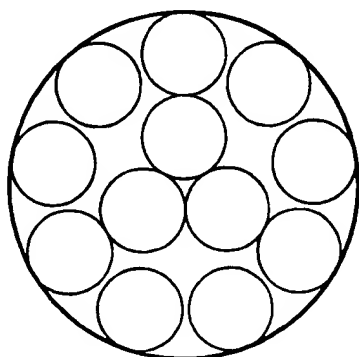


FIG. 17c

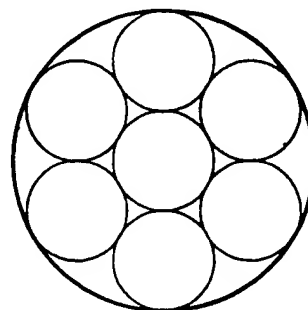


FIG. 17d

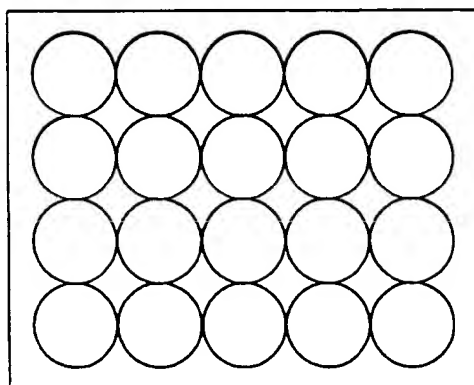


FIG. 17e

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US98/18634

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : G01N 1/00

US CL : 422/103; 285/121.3, 124.3

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 422/103; 285/121.3, 124.3

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ----- Y	US 4,726,932 A (FEIER et al) 23 FEBRUARY 1988, entire document.	1-3,6-18,20-26,29-31,33,35-39,43,52 ----- 4,5,19,27,28,32,3 4,40,42,44-51,53-60
X ----- Y	US 4,507,977 A (CABRERA) 02 APRIL 1985, entire document.	1-3,6-18,20-26,29-31,33,35-39,43,52 ----- 4,5,19,27,28,32,3 4,40,42,44-51,53-60



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	*T	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
*A* document defining the general state of the art which is not considered to be of particular relevance	*X*	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
*E* earlier document published on or after the international filing date	*Y*	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*A*	document member of the same patent family
*O* document referring to an oral disclosure, use, exhibition or other means		
*P* document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

14 DECEMBER 1998

Date of mailing of the international search report

26 JAN 1999

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## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US98/18634

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,615,291 A (HAYAKAWA et al) 25 MARCH 1997, entire document.	4,5,27,28
A	US 5,250,263 A (MANZ) 05 OCTOBER 1993, entire document.	1-60

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